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GENERAL ELECTRIC *Review*

FEBRUARY 1950
Vol. 53, No. 2

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Associate Editor

THE COVER

The high quality of these sintered parts—sleeve and thrust bearings, oil-pump and washing-machine gears, with their accurately shaped teeth and fine surface finish—affords superior performance, efficiency, and quietness in operation. Although initial material cost of powdered metal is higher than that of cast metal, savings are realized because less material is needed, waste is minimized, and machining may be eliminated. Various heat-processing methods for these and other metal products are described in this issue in the serial on p. 43.

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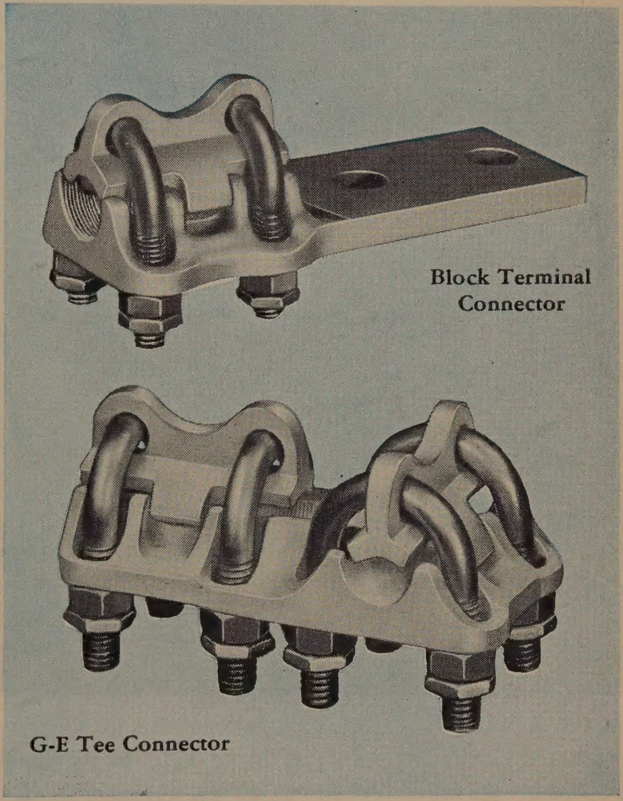

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GENERAL ELECTRIC

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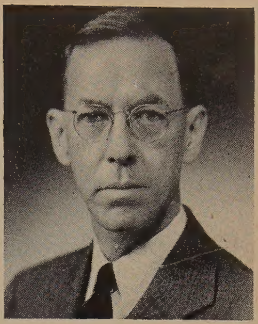
FOR ATOMIC POWER DEVELOPMENT

Members of the staff at the Knolls Atomic Power Laboratory, Schenectady (N. Y.), including representatives of physics, chemistry, chemical engineering, metallurgy, engineering, health physics, and laboratory administration. The group typifies the breadth of science and technology engaged in atomic-energy development and the variety of engineering education needed in this work. (See p. 7.)

ENGINEERING EDUCATION FOR ATOMIC-ENERGY DEVELOPMENT

What knowledge and skills must one have to do useful work in the development of atomic energy for peacetime applications? The answer varies with the type of work from procurement of raw materials, through research, design and construction of utilization equipment

By DR. K. H. KINGDON
Knolls Atomic Power Laboratory
Operated by General Electric Company
For U.S. Atomic Energy Commission



K H Kingdon

ABOUT 60,000 people are now engaged in the new and potentially large field of atomic-energy work. At present these people are employed directly by the Atomic Energy Commission and its contractors. If the production of power from atomic energy becomes an economic reality, such production will doubtless be participated in by private industry and will demand additional technical people. However, the following quotation from a report of the Industrial Advisory Committee to the Atomic Energy Commission indicates that the scope of opportunity in the field of atomic energy is not too clear.

> "It has been stated that industrial opportunities in atomic energy are potentially unlimited. They are at present so shadowy that business men neither know where to look nor what to look for."

This article will deal only with the present and possible future needs for technical people in this work. It will automatically bring with it some appraisal of the scope of opportunities offered by the development of atomic energy. The comments are restricted entirely to peacetime applications of atomic energy, although the production of fissionable materials such as plutonium is, of course, of fundamental interest for both military and peaceful applications.

There are three major fields of effort in the nonmilitary applications of atomic energy, as follows:

(1). The production of raw materials
(2). The utilization of radioactive materials produced by nuclear reactors in science and in industry
(3). The production of useful power.

The third of these fields will be the one given major consideration in this article but all of them will be included in the aim to gain an understanding of what kinds of technical people, and how many of them, may be needed for developments in the future.

PRODUCTION OF RAW MATERIALS

The production of raw materials is, of course, the first task. Uranium ore, the primary raw material of atomic energy, is distributed widely throughout the earth's crust, but most of the deposits are of such low grade that they are uneconomically expensive to refine. The United States at present obtains most of its uranium ore from the rich deposits of the Belgian Congo, while the relatively small production in this country has been from the lower-grade carnotite ore of the Colorado plateau. An intensive search for new uranium deposits is going on in this country and throughout the world, and this search has progressed sufficiently for the Atomic Energy Commission to report that there is an adequate supply of uranium to permit the use of atomic energy for power on a substantial scale.

The techniques used so far in the preparation of raw materials have been mainly adaptations of those common to the mining and ore-refining industries. The ore is dried, crushed, ground, weighed, sampled, packaged, and chemically analyzed. The analysis (or assay) establishes the uranium content of each batch of ore. This analysis must be accurate since it determines the amount of the payment to the ore-producer and is the basis for the record used in accounting for the uranium.

After it is assayed, the raw material goes to chemical refineries for production of uranium hexafluoride gas or uranium-metal slugs. By ordinary industrial operations in metal-working plants, the metal slugs are converted to rods of suitable size and shape for use in reactors.

Although much higher standards of purity are required, the atomic-energy-raw-material industry is not very different from other refining and chemical industries up to the point of use of the material in reactors. It is expected that men with the conventional training of mining and chemical engineers and metallurgists will be able to handle these jobs. How many such men will be needed in the future depends on the extent of the development of atomic power.

UTILIZATION OF RADIOACTIVE MATERIALS PRODUCED BY NUCLEAR REACTORS

Radioactive isotopes for scientific, medical, agricultural, and industrial uses are at present the main peacetime contribution of the development of atomic

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

energy. These isotopes are produced in nuclear reactors in three ways:

(1). By separating out the fission products resulting from the decomposition of the fuel

(2). By the capture of neutrons in the nuclei of atoms of special "target materials" inserted into the reactor—the target material thus becoming a heavier isotope of the same chemical element

(3). By altering the electrical charge of the nuclei of atoms of the target material and thereby transmuting them into isotopes of a different chemical element.

The fission products are by far the most abundant source of radioisotopes at present, but most of the radioisotopes usefully employed today in medicine and science are prepared by the second and third methods.

Medicine and biology at present constitute the largest fields for the use of radioisotopes, and absorb about 45 percent of the isotope shipments. Research in chemistry and physics accounts for another 36 percent of the shipments, while the uses which are classified as industrial and metallurgical amount to only some 10 percent of the shipments. It is to be expected that the industrial uses of radioisotopes will expand as time goes on, but many of the industrial applications which at first sight seemed important have not proved out well on further study.

All applications of radioisotopes require special instruments such as radiation counters, ionization chambers, scaling circuits, personnel radiation meters, film badges, lead bricks, and tools for the remote handling of radioactive materials. The uses of these special tools fall into two categories:

(1). The experimental work for which the radioactive material is being used

(2). Instruments used by "health physics" people to ensure that personnel are not exposed to dangerous doses of radiation.

The demand for these special instruments is, of course, common to all activities of atomic-energy work. This demand has led to the building up of a sizeable new radioactive instrument business, and there are now more than thirty firms supplying equipment of this sort. These firms employ physicists, chemists, and engineers who have specialized in instrumentation.

The people who are making use of these radioactive materials can hardly be classified as a new group of technical people working mainly in the field of atomic energy. They are, rather, primarily workers in the medical and biological sciences and other sciences, who are making use of by-products of atomic energy as a new tool in their respective fields. For example, the use of radioactive tracers in biology is said to be the most useful new biological tool since the invention of the microscope. The number of people using this new tool of radioactivity will depend upon the extent of the activities in their various fields of research and technology, and it is not to be expected that the new tool will cause a large increase in the number of people engaged in these fields. Fundamental training in the use of the new tool can come from suitable university courses, but detailed skills will probably have to come from actual practical work in the radioisotope laboratory.

PRODUCTION OF FISSIONABLE MATERIALS AND OF USEFUL POWER IN NUCLEAR REACTORS

The production of useful power from atomic energy and the creation of new fissionable material for use as fuel are accomplished by means of nuclear reactors. The concept of a nuclear chain reaction, as used in a nuclear reactor or pile, has become a familiar one.

A nuclear reactor is a very special assemblage of fissionable fuel, moderating material to control the energy of the neutrons, coolant to remove the heat, various structural materials to form the supporting framework, shielding to confine the intense radiation, and some means for controlling the rate at which the nuclear reaction proceeds. This whole assembly is so proportioned that the neutrons liberated from the fission of one atom of uranium will cause the fission of just one more atom of uranium, so that the fission process is self-sustaining and the nuclear chain reaction proceeds.

The consumption of nuclear fuel in a reactor is similar in many ways to the burning of conventional fuels in a furnace, and it is instructive to compare corresponding items in the two cases and to note similarities and differences. This comparison will also offer a convenient way of assessing the technical skills which will be required in the design, construction, and operation of the power and breeding reactors of the future.

Fuel

We are all familiar with the conventional fuels—coal, oil, and gas—and have some idea of the rather elementary chemical and mechanical processing which is necessary to prepare these fuels for burning in a conventional furnace.

The fissionable material so far used as a fuel has been in the form of a metal or an oxide or a solution of a chemical compound. The preparation of nuclear fuels was briefly described in the section on raw materials, and it was pointed out that, in general, the preparation followed conventional mining and metallurgical processes, except for the requirement of unusually high purity. In addition to this requirement of purity, nuclear fuel in most cases will need a relatively large amount of fabrication to fit it for use in the reactor. This arises mainly from three causes:

(1). The need to control the radioactively dangerous fission products formed when the fuel is consumed

(2). The extremely high energy concentration in the fuel

(3). As a corollary to (2), the desire to obtain relatively enormous heat transfer from a given amount of nuclear fuel as compared with an equal amount of ordinary fuel.

t will be evident from this that much more metallurgical and mechanical skill will enter into the fabrication of nuclear fuel than is the case with conventional uels.

Heat Transfer

The heat transfer in a conventional furnace is usually accomplished by passing the hot gases from combustion over pipes or surfaces through which the heat energy of the gases is removed by transfer to a liquid coolant. Especially in the case of land installations, there is no compulsion to make the furnace very small and the over-all size is fixed by conservative practice regarding the life of the heat-transfer surfaces.

In a nuclear reactor, there are two compelling reasons for getting the maximum possible heat transfer out of the smallest possible volume:

(1). It is evident that if the fissionable fuel is compactly arranged there will be less chance for neutrons to escape from the reactor than if the fuel were rather widely dispersed and that, therefore, a compact structure will conserve fuel

(2). Nuclear fuel is so expensive that it is profitable to invest a considerable amount of mechanical and metallurgical effort in getting the maximum possible amount of heat out of a given amount of this fuel, thus getting a better return on the investment in fuel.

The existence of these boundary conditions implies that a great amount of engineering effort will be put into the heat-transfer problems of nuclear reactors just as considerable effort has gone into the engineering design of a compact radiator for automobiles. The services of skilled heat-transfer engineers will be at a premium in the nuclear-reactor field for some time.

Corrosion

The problems of corrosion in conventional combustion are familiar and include attack of materials by chemically active components of the combustion gases, and corrosion of materials by the liquid coolant medium. The conventional engineering materials give impressive performances in resisting corrosion.

The materials of the nuclear reactor are also subject to conventional corrosion by the gaseous or liquid coolant but with the added difficulty that maintenance of the inner parts of a reactor is extremely difficult, if not impossible, on account of the intense levels of radioactivity which prevail there even after the reactor has been shut down. The results of a corrosion failure are probably also more serious in the reactor than in the conventional furnace, although probably no more serious than the effects of a corrosion failure in certain types of chemical engineering apparatus. The solution of these problems will require the services of chemists and metallurgists.

Radiation Stability

The problem of radiation stability has no counterpart in the conventional furnace. The interior of a nuclear reactor is filled with almost inconceivably intense radioactive radiations, particularly gamma rays (x-rays) and neutrons. Both these radiations have the ability to penetrate considerable thicknesses of the materials within the reactor and to cause displacements of the atoms of these materials. These displacements may result in a kind of internal corrosion of the materials in the reactor which would make them unfit for prolonged operation. Much experimentation by physicists and metallurgists will be needed to determine which structural materials can satisfactorily withstand the intense radiation conditions within a reactor.

Neutron Spectrum

The neutrons produced in fission start out with very high velocity. They may be utilized to maintain a chain reaction while still at this high velocity, as is done in the case of the atomic bomb. They may be slowed down by a moderator to relatively low velocities, comparable to those of the gas molecules in ordinary air, and used to sustain the chain reaction under these conditions. This is the situation in most reactors which have been built to date. Alternatively, the neutrons may be used in the reactor at some velocity intermediate between the fast and slow regions. This is the case for the reactor being built at the Knolls Atomic Power Laboratory.

Each of these regions of neutron velocity has certain advantages for use in reactors designed for power and breeding, and much physics experimentation will be required to assess these advantages quantitatively and to decide what is the best neutron spectrum to use for a given purpose.

Neutron Economy

Only a strictly limited supply of neutrons is produced by fission but these neutrons are essential for the maintenance of the chain reaction and for the production of new fissionable material which is so vital to the development of a large atomic-power industry. It is evident, therefore, that the neutrons must not be wasted by absorption in materials or poisons which play no vital part in the over-all economy of the nuclear reactor. This condition forbids the use of many of the conventional and well-tried materials of engineering practice in certain types of nuclear reactors and brings with it the necessity for exploiting new and untried materials. A large amount of metallurgical work will be needed to bring the technology of these new materials to a point where it will be adequate for their extensive use in nuclear reactors. There will also be need for tests of the nuclear properties of these new materials by physicists.

Control

The control of a conventional furnace is very familiar and involves regulating the supply of fuel through pipes or stokers and regulating the supply of air with blowers or dampers.

The concentration of energy in nuclear fuel is so enormous, and the necessary initial charge, or critical mass, of nuclear fuel is so large compared to the rate at which it is burned up, that it probably will seldom be necessary to refuel a power reactor while it is in operation, and it certainly would be difficult to control the rate of energy generation in the reactor by a refueling process. Instead, some means is used to alter the number of neutrons present in the reactor at any instant, so that this number slowly increases or decreases. For example, some material such as boron, which absorbs neutrons, may be introduced into the reactor, or some part of the covering of the reactor may be removed so as to allow neutrons to escape from the active portion. This control change then permits the number of neutrons to increase or decrease to some desired value at which a further change in the controls is made to hold the neutron population and, therefore, the power production in the reactor, at the desired new constant level.

The mechanisms by which the control elements are moved involve familiar principles of mechanical and electrical control engineering, and engineers who work effectively in this field may be adequately trained by conventional university courses, followed by practical experience.

Introduction of Fuel and Removal of Products

As has been mentioned, the fuel for a conventional furnace is introduced by means of a stoker or a pipe. The products of combustion are removed either as flue gases or as ash. Relatively simple structures and mechanisms can accomplish both of these processes.

The problems of feeding and removing fuel are much more complicated for the nuclear reactor on account of the high level of radioactivity which prevails within the reactor, even after it has been shut down for some time. This condition requires that the new fuel be introduced, and the spent fuel be removed, by some remotely controlled mechanism. These mechanisms vary greatly in complexity with the type of reactor they are to service. The more complicated ones offer a remarkably fertile field for the talents of the expert mechanical designer.

Shielding

A conventional furnace is boxed in to retain the hot gases and is lined with materials which will not readily transmit heat.

This problem of shielding against heat also is present in the nuclear reactor, but in addition there is the far more difficult problem of shielding against the escape of the penetrating gamma rays and neutrons which were mentioned before in connection with radiation damage. The physical principles underlying shielding are well understood. The escaping neutrons must be captured by a nuclear process, and the ability of various substances to capture neutrons is rather well known. The problem is complicated a little by the fact that many of the processes by which neutrons are captured involve the emission of a gamma ray so that this ray must be subsequently absorbed in the shield. The absorption of gamma rays requires materials of high density so that a gamma-ray shield is always heavy. Although it is true that the fundamental principles of shielding are understood, it is also true that the detailed design of a shield for any particular application still requires involved physics calculations and skilled engineering design. This is particularly true if the shield is for a reactor on a ship, where conservation of weight and space is important.

Chemical Processing of Used Fuel

The chemical processing of materials removed from an ordinary furnace is rudimentary. The flue gases may be treated to remove solid particles, but the ashes are usually discarded without further ado.

On the other hand, materials removed from a reactor require elaborate chemical processing. In most cases some new fissionable material such as plutonium will have been produced. This must be chemically separated and worked into a form suitable for use. Any unconsumed residue of the original charge of fuel must be recovered since it is valuable material, and, finally, the fission products must be separated and disposed of. Some of the fission products absorb neutrons, but in an entirely useless way, so that if they are not periodically removed from the reactor they will impair its efficiency.

All of these materials coming out of the reactor are highly radioactive and the chemical operations carried out on them must be remotely controlled. This, then, is a challenging field for the chemist and the chemical engineer, and revolutionary progress must be made here before it will be possible to have an economically sound atomic-power industry.

Waste Disposal

The disposal of flue gases and ashes from a conventional furnace is a simple matter, but this is far from being true for the highly radioactive wastes from the chemical processing plant for a nuclear reactor. The radioactivity of these wastes comes almost entirely from the fission products, and while it is true that a small amount of these may be put to some useful purpose in medicine or other fields of science, most of the fission products must at present be disposed of as waste.

The sea is a very big place, big enough to accommodate safely all the fission products that would be produced by a sizeable atomic-power industry provided that they could be uniformly distributed throughout the oceans of the world. This is difficult to guarantee and there is always the serious chance that some fish will eat the concentrated fission products or that they will be picked up by some marine vegetable growth. The tolerance of some forms of marine life for radioactivity is much greater than human tolerance, so that procedures cannot be allowed which might permit humans to catch and eat highly radioactive fish or marine lora. In view of such considerations, it seems safer to oncentrate the liquid and solid radioactive wastes to mall volumes and to store them until a national policy or the safe disposal of these wastes is decided upon. A ossible procedure might, for example, consist in mixing oncentrated radioactive wastes with concrete and umping the concrete blocks into the sea.

The problem of waste disposal is thus another one n which a great deal of chemical and chemical engineering talent can be used. Not only should satisfactory ays of dealing with the wastes from existing processes e worked out but new chemical processes should be developed which produce smaller initial volumes of waste, and those in a more convenient form for disposal.

Production of New Fuel

The conventional furnace consumes fuel without producing a new supply of fuel to replace that burned up. One of the most remarkable things about a nuclear reactor is that there is the possibility of using some of the excess neutrons produced in fission to make a fresh supply of fissionable material. The new fissionable materials are made by the interaction of neutrons with uranium-238 or with thorium, which are called fertile materials and are specially placed in the reactor for this purpose. If the amount of new fissionable material produced exceeds the amount burned up, the reactor is said to be a breeder.

The only useful fissionable material found in nature is uranium-235, and this is rather rare since it constitutes only one part in 140 of natural uranium. The possibility of breeding opens up the prospect of converting all the uranium-238 and all the thorium into useful fissionable material and thus increasing the supply of fissionable material by a factor of several hundred. Thus the satisfactory development of breeding is of the greatest importance for the establishment of a large atomic-power industry, and the development of power-breeding reactors will be a major task for technical people working in this field.

KINDS OF TECHNICAL PEOPLE NEEDED FOR ATOMIC POWER DEVELOPMENT

This brief survey of reactor problems has shown something of the variety of technical people needed for atomic-power development. The list includes chemists, physicists, metallurgists, and chemical, electrical, and mechanical engineers, and it is evident that some of these people will need training in the new fission and neutron physics and in the handling of intensely radioactive materials.

It will be instructive to take a closer look at the staff of the Knolls Atomic Power Laboratory. This laboratory is entirely concerned with the development of atomic power and has no research work going on in other fields. The technical personnel of the laboratory is divided among the various functional divisions as shown in Table I.

TABLE I

Administration	3 percent	
Physics	22 percent	2/3 nuclear
Chemistry	18 percent	2/3 separations radiochemistry, "hot" chemistry
Chemical Engineering	16 percent	"hot" separations chemical engineering
Metallurgy	17 percent	
General Engineering	21 percent	heat transfer, mechanical, electrical
Health Physics	3 percent	
	100 percent	

Only about 15 percent (2/3 of the physics groups) of the staff need to have expert knowledge of reactor neutron physics and general neutron physics. Most of the chemists and chemical engineers need knowledge of radioactive materials in addition to their usual training.

Most of the physicists have had good graduate training in nuclear physics and acquired the necessary specialized reactor neutron physics in a relatively short time in this Laboratory or elsewhere. Most of the chemists were specialists in various standard fields and acquired their knowledge of handling radioactive materials in this or other Commission laboratories. It is not possible at present to get much of this type of "hot chemistry" training in universities, since the special facilities for handling large amounts of radioactive materials are available in only a few places.

All the engineers have had the standard kinds of training in their respective fields. It was thought that some general indoctrination in the field of atomic energy was desirable for the engineers and certain others of the staff, and two kinds of courses have been given in the Laboratory to achieve this end. The first kind of course, known as the "Advanced Course," aimed at making certain selected engineers familiar enough with the neutron physics of reactor design to enable them to carry out a large part of the engineering design of a reactor without help from physicists. This will certainly be the state of affairs when there is a well-established commercial reactor industry, but in the present state of development it seems easier to employ physicists for much of this work, and the advanced type of course has been discontinued for the present. The second kind of course, known as the "Project Course," is of a more popular nature and is the sort of course to which a majority of the staff should be exposed. The work of this course is about evenly divided between nuclear physics, reactor neutron physics, and reactor technology, including metallurgy.

The development of an atomic-power industry is analogous in many ways to the petroleum industry. It will have similar problems of developing sources of raw materials. Radioactive prospecting will parallel the acoustic prospecting of the oil industry, and new metallurgical processes for refining the ore will take the place of the stills and columns of the petroleum refining industry. The construction of oil-fired power boilers will be paralleled by the development of atomic furnaces or reactors for generating useful heat, although it must be admitted that the latter task looks like a considerably more difficult problem at present. Useful by-products will come from the reactors of the atomic-power industry just as they do from the refineries of the petroleum industry.

It must be remembered that no reactor for the production of useful power has been built and tested yet. It will probably be about three years before any of the new reactors now planned will start to yield useful data. These reactors now include:

Argonne–Oak Ridge	Materials Testing Reactor
Argonne	Experimental Breeder
Knolls Atomic Power Laboratory	Power and Breeding
Argonne–Westinghouse	Ship Propulsion

The comparison with the petroleum industry, faulty though it is, enables one to get some sort of perspective on the technical manpower needs of this possible new industry in relation to the national picture. The sixteen largest oil companies employ some 4000 engineers, and another considerable number of engineers are engaged in the manufacture of furnaces and boilers.

It is to be expected then that a considerable atomic-power industry would use a few thousand engineers and scientists. By way of comparison it may be noted that the General Electric Company employs in its various laboratories, and design, application, and manufacturing divisions about 9000 scientists and engineers, and that there is a national pool of some 300,000 engineers and 150,000 scientists of all sorts. It should also be noted that in this country in 1948 there were 32,000 bachelor's degrees, 5400 master's degrees, and 198 doctor's degrees granted in engineering. The probable demands of a considerable new atomic-power industry can therefore hardly be regarded as a substantial additional load on the engineering schools of the country.

To summarize, it may be stated that most of the technical people to be used in the atomic-power effort in the future will need training in special fields of current engineering, and in physical, chemical, and metallurgical skills. Perhaps ten percent will need the new fission and neutron knowledge of modern nuclear physics. Some of this they will be able to get in universities, but security restrictions and the probable continued general unavailability of nuclear reactors and other expensive and restricted equipment and materials will mean that much of the specialized technical knowledge will have to be obtained on the job.

A considerably larger group than the ten percent mentioned, and consisting of chemists, chemical engineers, and health physicists, will need practical knowledge of how to handle radioactive materials in bulk. Here, again, this knowledge will probably have to be obtained on the job.

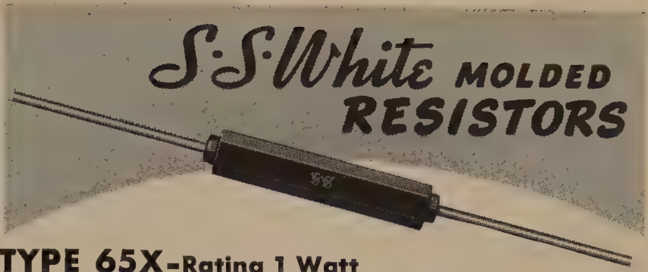
No consideration of technical personnel for atomic-energy work should, for the present at least, fail to include the effect of security regulations on the hiring of competent people and on keeping them satisfied after they are at work. In our experience to date in the Knolls Atomic Power Laboratory there has been very little difficulty about the security clearance of our technical people, and clearance has been denied in only about one percent of our applications. Without attempting to say whether the denial of clearance was justified in these cases, their number is so small that the effect on the program obviously cannot be serious. On the other hand, the denial of clearance is a serious matter for the individual concerned, and may affect his whole future, so that it is essential to make the clearance procedures as fair and objective as possible. It requires about two or three months to process a clearance request and this initial delay must be allowed for in planning the time at which new men can become active in the program.

We have had much less difficulty than was expected with the enforcement of adequate security regulations concerning access to the Laboratory and the safeguarding of classified materials and documents containing restricted data. Security regulations do complicate the operation of the Laboratory but one gets used to such things as carrying passes, putting documents away in safes, and not talking indiscriminately about the work of the Laboratory.

The attitude of the technical staff has been one of cooperation with intelligent security regulations. Much of the violent opposition to all security regulations may come from people who have an extreme sense of personal prerogatives and personal liberty. Such people in general do not make very good members of a team, and as most of the projects in atomic-energy laboratories are large enough to require team work, it is well to avoid having too many ardent individualists on the staff. Based on our experience in the Knolls Atomic Power Laboratory, extreme statements that security regulations in AEC laboratories effectively prohibit good scientific work should be discounted.

A more serious difficulty is occasioned by the necessity for withholding temporarily the publication of many of the results of technical work in a classified field. One of the major objectives of a good technical man is to build up a reputation in his field by publicaion of results, and the satisfaction of knowing that his ork is appreciated by an intelligent audience should ot be denied him. This need is to some extent met by requent personal visits between AEC laboratories, by xtensive circulation of classified reports, by the publiation of classified journals, and by personal contacts vith some of the most distinguished university and ndustrial scientists who are employed as consultants. By these means a scientist who is working on a classiied project is assured that his efforts are presented to hose best fitted to appraise them, and that he can build reputation on a national scale without necessarily ublishing a single paper in a conventional scientific ournal.

A final word should be said about the calibre of these en. The work that they will be doing in the immediate uture will be concerned with radically new developments and there will be practically nothing of the handbook type of engineering. The laboratories and organizations responsible for these developments should ecruit the highest calibre of engineering talent. Many of the men should be young, with the fresh viewpoint and enthusiasm characteristic of youth. These should be leavened with a sprinkling of more experienced people to supply a background of mature engineering judgment. With a competent staff of this sort, and with the substantial financial backing which the government is giving to this enterprise, satisfactory progress should be made during the next few years.



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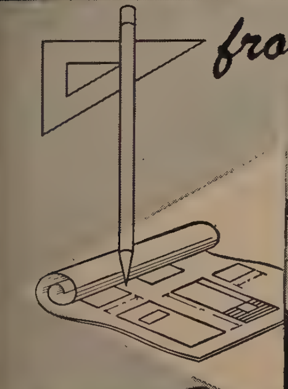

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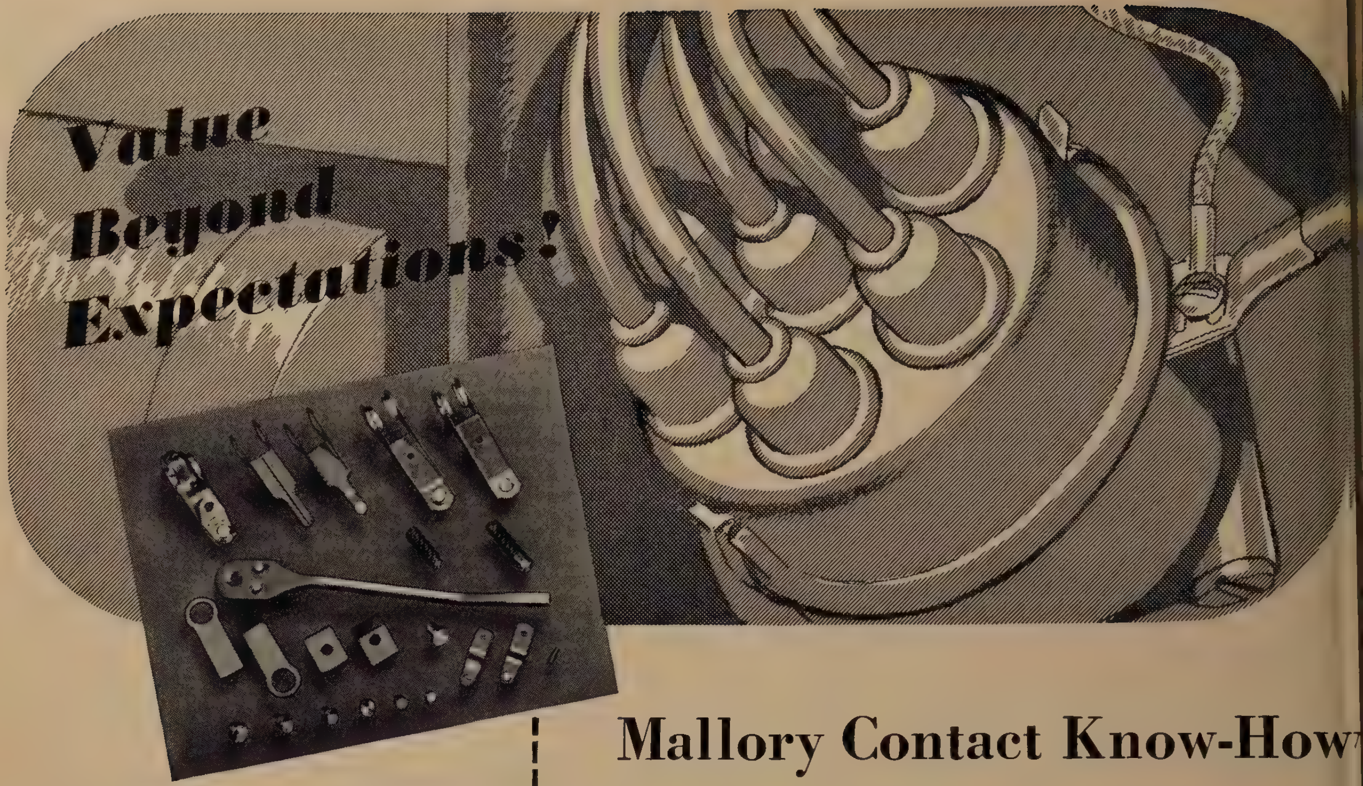
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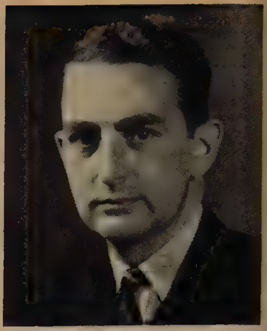
STANDARD TRANSFORMERS FOR PLANNED A-C SECONDARY NETWORK SYSTEMS



T. E. Rodhouse

Improvements in the manufacture, installation, service, and operation of modern transformer equipment accompany the advances that have been made toward standardization of its design

By T. E. RODHOUSE
Transformer and Allied Products Division
Pittsfield Works, General Electric Company

STANDARDIZATION of equipment invariably expedites technical advancement, reduces costs, improves quality, and shortens shipment. It is enlightening to note the effect of progress toward standardization of network transformers in terms of actual improvements in design and deliveries of units from the factory as well as the advantages that mark their application and use.

Shipping promises for standard designs of network transformers are several months less than for special designs. This is true in spite of the fact that considerably more than twelve months have been removed from the shipping promises that were necessary shortly after the end of the World War II. Improved schedules of deliveries, so important in present reduced inventory plans, are possible because standard designs allow reasonable stocking of raw materials, finished component parts, elimination of special engineering and drafting time, and simplification of factory instructions. Actual manufacturing time is greatly reduced by quantity production of parts, thereby reducing machine setup time and also by familiarity with manufacture and assembly gained by workmen on repetitive operations obtained on standard equipment. Fig. 1 illustrates the production assembly line possible with similar standard network transformers.

Technical advancement is speeded up tremendously by standardization. In Fig. 2 the tailor-made 300-kva network unit of 1929 is compared to the present standard unit of the same rating. If all network transformers were special, most or all available engineering and drafting effort would be used in producing them. On the other hand, standard designs free the engineering and drafting personnel for development and improvements in the standards. Figs. 3, 4, and 5 show the evolution of the 500-kva standard network transformer.

An analysis of the over-all problem of installing network transformers in vaults indicated that the secondary connections to the network protector bushings require approximately the same headroom as the primary connections (Fig. 6). Therefore, the complete unit, including the network protector, should be considered and not the transformer alone. With this in mind, a balanced design was obtained by lowering both the primary and secondary connections to the practical minimum. The effectiveness of this change can be seen by comparing Fig. 4 with Figs. 5 and 6.

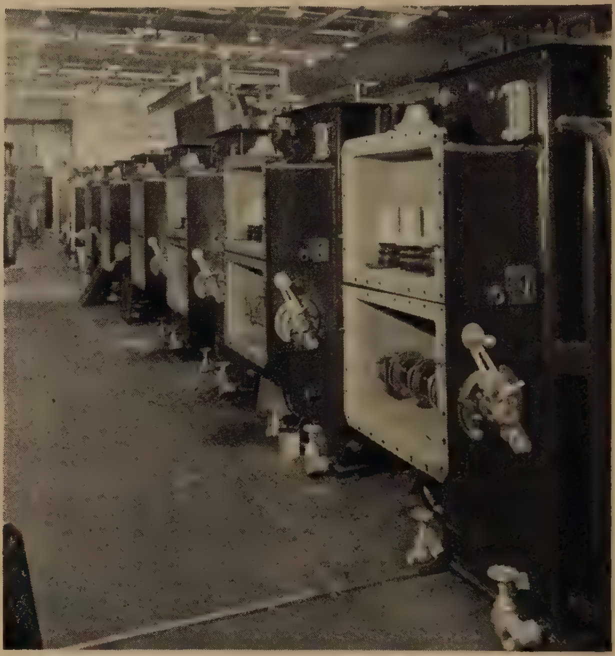


Fig. 1. Assembly line of standard network transformers of similar ratings

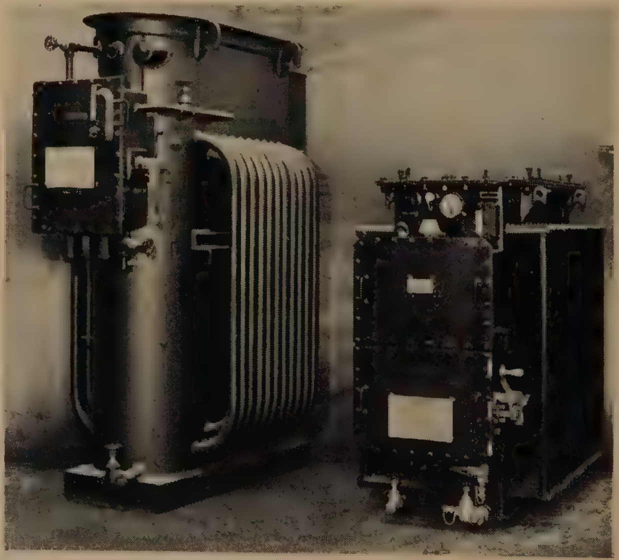


Fig. 2. Three-phase network transformers rated 300 kva, 60 cycles, 13,750 to 216Y/125 volts. Lefthand unit manufactured in 1929. Righthand unit manufactured in 1948

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

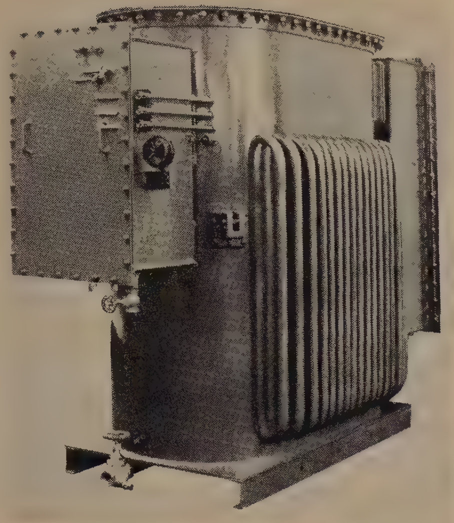


Fig. 3. Three-phase network unit consisting of 500-kva transformer and network protector. Manufactured in 1928. Vault required, approximately 17 ft by 4 ft 6 in. by 9 ft deep

Most network system operators have seen a steady and rapid load growth on their secondary networks. This load growth has imposed a serious problem of interchangeability and made it desirable that units of different kva ratings be kept interchangeable so that transformers may be replaced by larger sizes with the minimum of expense and time. Present standard network equipment is interchangeable to the extent that little or no trouble should be encountered in replacing a 300-kva unit with a 500-kva unit. Generally, this change does not necessitate any cable cutting or splicing. A 750-kva transformer may be replaced with a 1000-kva unit in like manner. In many cases it will be possible to replace a 500-kva transformer with a 750-kva with only slight rearrangement of primary or secondary cables, provided the cables are of sufficient size to carry the increased load.

To increase the usefulness of these compact three-phase standard units, many other operator benefits have been added by a similar analysis of the installation and maintenance problems. The following review of improvements in standard network transformers since their introduction in 1939 will confirm the statement that standardization expedites technical advancement. These improvements were all made to reduce the cost of installation and maintenance of network transformers.

Cable Connections: Undoubtedly the most important mprovement is the lowering of the primary and secondary cable connections. As previously outlined, this change allows the installation of units in vaults of ninimum height. The convenience of such arrangement s shown in Fig. 6. Another improvement accomplished n the new location of cable entrances is the convenient working height for making primary cable terminations. Most of the cable work will be at eye level or slightly ower, eliminating tiresome, crowded, and inefficient working conditions. The space for forming and taping primary cables inside the high-voltage terminal chamber has been enlarged to further facilitate this work. This is shown in Fig. 7.

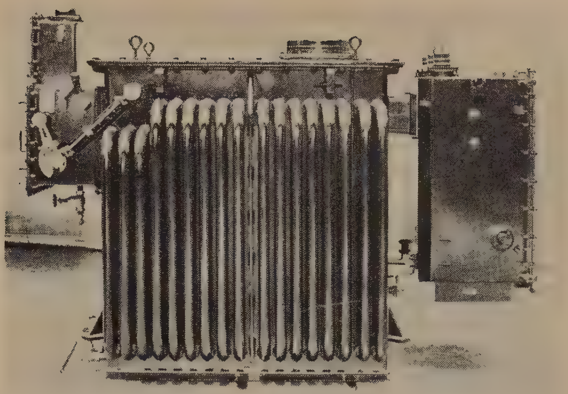


Fig. 4. Three-phase network unit consisting of 500-kva transformer and network protector. Manufactured in 1939. Vault required, approximately 14 ft by 4 ft 6 in. by 7 ft deep

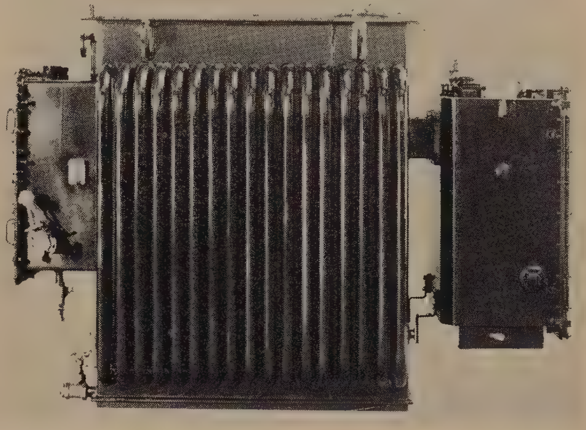


Fig. 5. Present standard three-phase network unit consisting of 500-kva transformer and network protector. Manufactured in 1948. Vault required, approximately 14 ft by 4 ft 6 in. by 7 ft deep. This design gives improved cable room

Maintenance: Maintenance of gaskets has been one of the greatest problems for operators of network systems. To reduce gasket maintenance on standard network transformers, the high-voltage disconnecting and grounding switch is now welded to the main tank. The practice of also welding the main tank cover onto the tank is highly regarded and eliminates the largest gasketed surface on the unit. It is necessary to remove the cover weld and reweld in case the unit must be

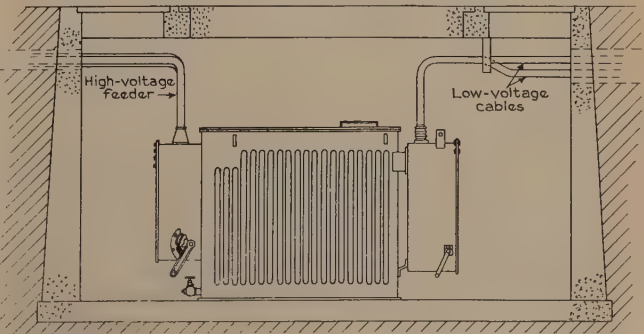


Fig. 6. Elevation view of network vault, showing standard network transformer installed. Note the simplicity and neatness possible with this arrangement

untanked, but this is not a frequent operation, usually never occurring in the normal life of a transformer. In fact, most repairs requiring the removal of the main cover are usually done in a service shop where burning and welding equipment is available. Most of the larger systems and many of the smaller ones now specify welded-on covers. To our knowledge, no user of standard network transformers has reverted to the gasketed cover after once obtaining a unit with the welded-on cover.

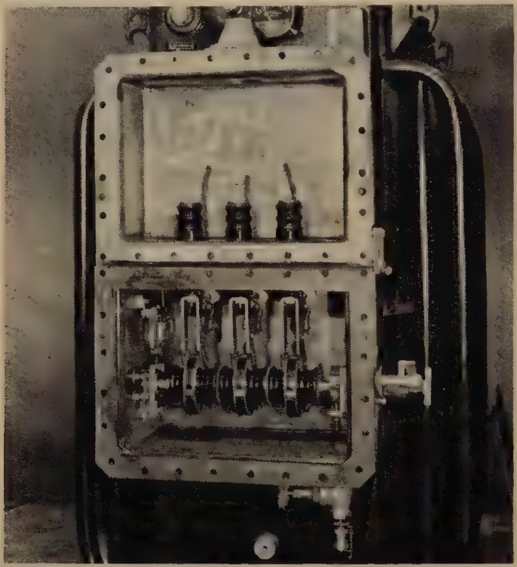


Fig. 7. Three-pole three-position disconnecting and grounding switch. View showing switch contacts, electric interlock, and high-voltage terminal chamber. Switch is shown in closed position

Bushings: To reduce the number of gasketed handholes to a minimum and to assist in the convenience of welded-on covers, both high-voltage and low-voltage transformer bushings are externally removable, as shown in Fig. 8. The porcelains or gaskets of these bushings can be replaced from the outside of the tank without removing the main tank cover or handhole cover.

Gang-operated Tap Changers: The standard tap changer is gang-operated with the control located behind a two-inch pipe plug in the high-voltage end of the tank. This arrangement eliminates the expensive externally operated mechanism and packing gland, and the tap changers are operated with a standard socket wrench inserted through the pipe plug opening to engage the hexagonal end of the common operating shaft. Positive positioning is assured by the snap-action of the tap changer and the elimination of any external drag associated with a packing gland.

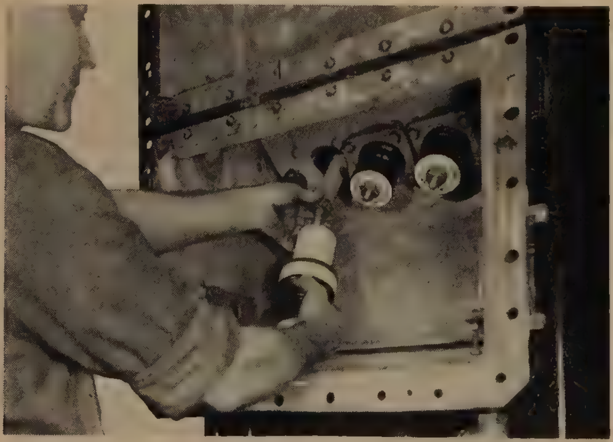


Fig. 8. Externally removable bushings. This view shows the high-voltage bushing between transformer and high-voltage switch

Most operators now believe that they cannot justify the additional cost of the externally operated drive, because they find that taps are seldom, if ever, changed after a unit is installed in a given location. This feature has the added advantage of eliminating the packing gland between the tank wall and the operating shaft, which has previously been a source of maintenance trouble. Operators have also pointed out that this drive has the additional advantage of greatly reducing the chances of operation of the tap changers by an unauthorized person, because the operating shaft is concealed.

Interior Design: Network transformers are almost always connected to systems of large capacity; therefore short circuits on the secondary network cause severe mechanical forces in the interior of the transformer. For holding the coils securely in place, heavy core clamps of structural steel shapes, substantial tie-rods, large coil supports, and numerous clamping bolts are used on the interior assembly, as shown in Fig. 9. The low-voltage bus bars also are securely clamped in position, and the number of flexible leads held to a minimum, to withstand extreme forces resulting from heavy short-circuit currents. Effective phase isolation of the high-voltage leads has been provided, thus reducing the possibility of a phase-to-phase fault inside the tank.

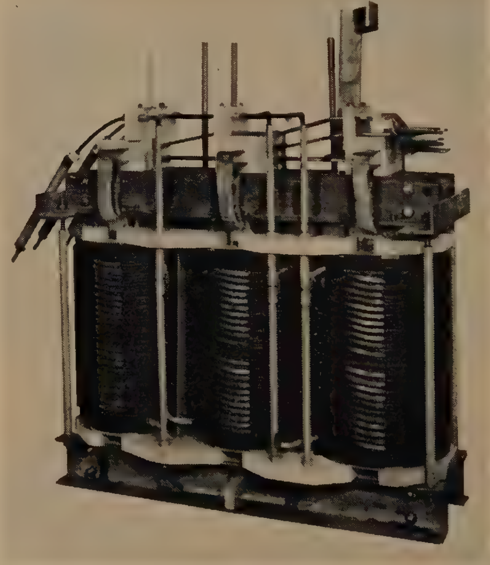


Fig. 9. Interior assembly of standard network transformer rated 500 kva, 60 cycles, 13,200 to 216Y/125 volts

Grounding Switch: To afford maximum protection to persons working on an installed network transformer, a three-pole three-position disconnecting and grounding witch (FIG. 7) is supplied with standard units. Because his switch is basically a safety device, a great deal of hought, work, and service experience attended its development and extreme care is exercised in its manuacture and assembly. For instance, the switch contacts are supported on porcelain insulators so that all of the major insulation in the switch is porcelain and liquid (oil or Pyranol). The switch has a mechanical sequence of OPEN, CLOSED, GROUND positions, in that order. In the OPEN position, the high-voltage cables are disconnected from the transformer windings. In the CLOSED position the high-voltage cables are connected to the transformer

TABLE I: STANDARD THREE-PHASE 60-CYCLE NETWORK TRANSFORMERS

Ratings, Kva:	300, 500, 750, 1000.
High Voltages:	2400, 4160, 4800, 7200, 12,000, 13,200, 22,000.
Low Voltages:	216Y/125 (preferred), 208Y/120.
Impedance:	Five percent.
Taps:	Four 2½ percent below rated voltage.
Tap-changer:	Units 5000 volts and below have terminal board located under handhole in cover. Units above 5000 volts have gang-driven tap-changers with single control located back of 2-in. pipe plug at high-voltage end of tank.
High-voltage Switch:	Three-pole three-position disconnecting and grounding switch (Fig. 10).
Switch Box:	Liquid-filled compartment welded to one end of tank.
Network Protector Support:	Provision for mounting submersible or non-submersible network protector on end of tank opposite switch (Fig. 11).
Accessories:	Thermometer, liquid-level gage, air test valve, liquid sampling valve (top sampling device for Pyranol units).
Accessory Location:	High-voltage end of tank (Fig. 10).
Drain Valve and Filter-press Connections:	Located at bottom of high-voltage end of tank and clearly marked by nameplate. Piping inside the tank obtains proper diagonal filtering (Fig. 10).
High-voltage Connections:	Compound-filled terminal chamber welded to the top of the switch box. Cable entrance is made through one three-conductor wiping sleeve (either straight or 45-degree) or three single-conductor wiping sleeves mounted on the top of the terminal chamber (Fig. 10).
Low-voltage Connections:	Stud-type bushings with flexible terminals for connection to submersible or nonsubmersible network protector located on end of tank opposite high-voltage switch (Fig. 11).
Low-voltage Neutral:	Located near top on right-hand side of tank (facing low-voltage) near the low-voltage end (Fig. 11).
Neutral Connection:	Copper bar inserted through tank wall and permanently welded to tank wall. Provision is made inside tank for disconnecting neutral for test (Fig. 11).
Bushings:	High-voltage and low-voltage bushings are removable externally without removing transformer cover.
Tanks:	All tanks are pressure-tight and suitable for submersion.
Tank-casing:	$\frac{5}{16}$-in. thick.
Cooling:	$\frac{3}{32}$-in. tube-wall is standard.
Tubes:	$\frac{5}{16}$-inch. tube-wall may be obtained for service where corrosion conditions are exceptionally severe.
Covers:	Welded covers on main tank are standard. Bolted covers on main tank may be obtained if preferred.
Handholes:	One handhole on cover near low-voltage neutral to allow disconnection of neutral ground for test. Pyranol transformers have pressure relief diaphragms over the handhole opening with diaphragm interrupter set to trip at 12 psi.
Liquid:	Cooling and insulating liquid may be oil or Pyranol.

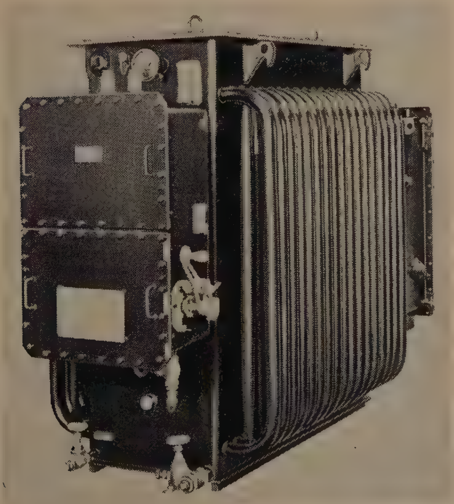


Fig. 10. Standard three-phase network transformer shown with the high-voltage switch at the left and a network protector unit attached to transformer at the right

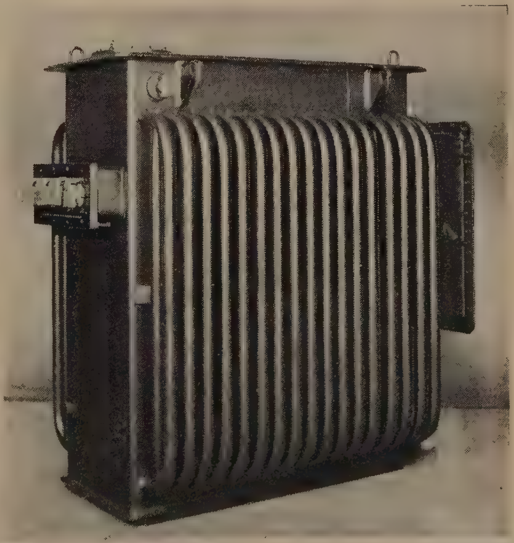


Fig. 11. Low-voltage end of standard three-phase network transformer showing low-voltage bushings, network protector support, and neutral connection

windings, and in the GROUND position the high-voltage cables are disconnected from the transformer windings and are short-circuited and grounded.

A mechanical time delay is incorporated in the switch operating handle located on the righthand side of the switch box. The mechanical time delay in the closed position prevents the switch being moved from the open position directly to the ground position without a pause in the closed position. This pause in the closed position is sufficient to allow an electric interlock to operate if the transformer is energized. This electric interlock will then lock the switch in the closed position as long as the high-voltage cables and transformer windings are energized and, therefore, will prevent the short-circuiting and grounding of an energized high-voltage cable.

The standard network switch is designed for de-energized operation only; that is, for operation with all voltage removed from the high-voltage cables or transformer windings. The electric interlock with its operating coil directly connected to the low-voltage windings of the transformer is supplied to prevent operation of the switch when the transformer is energized. This interlock holds the switch in position whenever there is voltage on the transformer, regardless of whether the transformer is energized from the high-voltage cables or the low-voltage (network) side. This interlock is of the locked-energized type; that is, the switch is locked in position when voltage is applied to the interlock coil and is unlocked when voltage is removed from the coil.

Special applications may require switches to break transformer no-load exciting currents, and network switches with auxiliary quick-break contacts are designed for this purpose. For proper and safe operation, these switches must be equipped with two electric interlocks:

One interlock is energized from the low-voltage winding of the transformer and designed to prevent operation of the switch from the CLOSED to the GROUND position when the transformer is energized, thus preventing the short-circuiting and grounding of an energized cable.

The second interlock, energized from the secondary network through an auxiliary switch in the network protector, is necessary to prevent operation of the switch when the protector is closed, thus preventing the breaking of load currents by the switch.

Standardization of network switches also contributed materially to their improvement. The most important of these improvements are simplification of design, assembly, and operation, reduction in size, elimination of flexible connectors, and the reduction in parts required (especially porcelains, which were reduced in number from eighteen to six.)

Table I shows the essential features of standard network transformers. The following is a brief summary of the more important improvements in network transformers accomplished by standardization.

Installation expense reduced by lowered cable terminations, permitting shallower, less expensive vaults, and more efficient and economical cable work in the vault.

Field maintenance and painting of the tank are made easier by larger space between cooling tubes and tank casing.

Expensive and troublesome gasket maintenance is reduced substantially by the welded-on high-voltage switch and main tank cover.

Porcelains or gaskets for both the high-voltage and low-voltage bushings may be removed and replaced externally without removing the main transformer cover.

Gang-operated tap-changer control, located behind a pipe plug, provides inexpensive regulating taps, eliminates packing gland maintenance, and gives protection against unauthorized operation.

Sturdy construction of interior and exterior insures long efficient life under severe operating conditions.

Improved and simplified disconnecting and grounding switch, with proper mechanical and electrical interlocks, offers maximum safety to workmen.

A greater degree of interchangeability between units of the same or in many cases different kva ratings facilitates replacement for maintenance or load growth.

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REDUCTION OF PRESSURE DROP ACROSS CYCLONE DUST COLLECTORS

A remarkable saving in power required for the process can be made by the up to 80 percent pressure recovery accomplished by variations in the structure of the dust-separating equipment

By F. B. SCHNEIDER
Locomotive Engineering Division
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Fred B. Schneider

INDEPENDENT of the design, all "cyclones," from the ancient centrifugal dust collectors to the modern vortex collector, suffer from a common handicap. This disadvantage is the large pressure drop caused by the whirling motion of the gas while performing the cleaning action. In addition, with higher dust-separation efficiency, the pressure drop increases, so that the highly efficient vortex collectors have a pressure drop which is a multiple of the pressure drop of the common centrifugal separators. Since the latter are mostly used in connection with the cleaning of large volumes of air, the power consumed is considerable; and even small reductions of the pressure will provide substantial savings of horsepower.

The consideration of reduction of the pressure drop must necessarily be divided into those aspects pertaining to ordinary centrifugal separators and those pertaining to vortex collectors.

CENTRIFUGAL SEPARATORS

As indicated by the distinction in the designation of types, there is no vortex air flow in a centrifugal separator. A large number of tests in many installations showed that, in such separators, the rotating flow possesses almost constant angular velocity. The air enters the separators with the minimum velocity(1)(2)(3)(4)* at which it is just able to transport the coarse particles whose separation is desired. Although it would seem logical that the separation efficiency could be improved by increasing the centrifugal force of the particles due to a higher tangential velocity of the rotating air in the separator, experience and the pneumatic conveying theory(4) prove that the reverse is the case. Therefore, these separators are being built solely for the purpose of attaining normal separation with the lowest possible rotary motion and the lowest pressure drop, restricted only by practical consideration of size and cost.

An almost standard design adhered to by many manufacturers is shown in Fig. 1. Similar structures were built more than one hundred years ago. It can be seen that the size of the collector depends upon the diameter of the inlet pipe only. In modern installations these pipes reach dimensions of more than three feet. The pressure drop across such a collector has been found as one inlet-pipe velocity head.(2) Assuming a velocity of 80 ft per sec in a pipe of 3-ft diameter, the power required to force the air through such a collector is 7.5 hp at a pressure drop of 1.4 in. water. A very simple way to reduce this loss is to build the inlet pipe 10 ft higher and to curve it downward toward the inlet of the collector. The descending part of the duct should be enlarged gradually(5) until the velocity of the air at the entrance to the collector is 60 ft per sec. Depending on the length of the downward sweep of the inlet pipe, a substantial pressure recovery can be attained in this pipe. In addition, the pressure drop across the collector will be reduced by 0.6 in. water because of the reduced inlet velocity.

The entrance section to the collector must be rectangular to keep the width of the inlet equal to approximately one-half of the diameter of the inlet pipe, as shown in Fig. 1. However, the height should be changed to increase the inlet area sufficiently to attain the lower velocity required. The resulting steep angle of the lower edge of the tangential inlet serves to prevent depositing of any material at the entrance because of the decreased velocity of the air. The total reduction of the

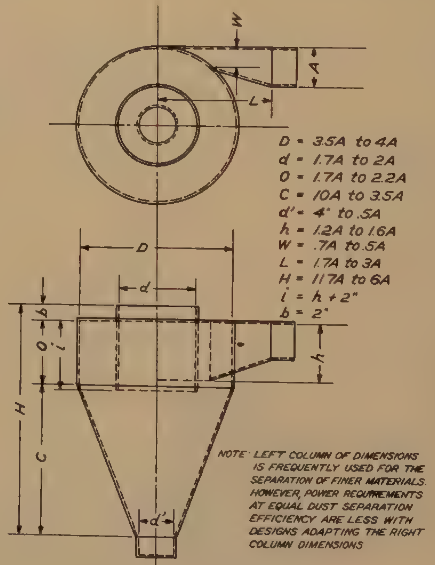

W
A
L
D = 3.5A to 4A
d = 1.7A to 2A
O = 1.7A to 2.2A
C = 10A to 3.5A
d' = 4" to .5A
h = 1.2A to 1.6A
W = .7A to .5A
L = 1.7A to 3A
H = 11.7A to 6A
i = h + 2"
b = 2"
D
d
b
O
i
h
H
C
d'
NOTE: LEFT COLUMN OF DIMENSIONS IS FREQUENTLY USED FOR THE SEPARATION OF FINER MATERIALS. HOWEVER, POWER REQUIREMENTS AT EQUAL DUST SEPARATION EFFICIENCY ARE LESS WITH DESIGNS ADAPTING THE RIGHT COLUMN DIMENSIONS

Fig. 1. Standard design of centrifugal separator

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

(1) Numbered references are listed at the end of the article.
*Minimum velocity 3000 ft per min, according to Sturtevant.

ressure drop due to the diverging pipe and the reuced entrance velocity is therefore 0.9 in. water, which results in a saving of 4.8 hp, or 64 percent in he example.

In addition to the reduction accomplished by this evice, the pressure drop can be lowered by rearranging he central outlet without influencing the separation fficiency. To prevent rain entering the separator, t is a standard practice to form the cylindrical inner utlet for clean air into a U-bend. This forces the outlowing air vertically downwards and keeps the inside lry. Since rotating air in any bends causes a high presure drop, everything possible should be done to force he air into parallel flow. Although this could be acomplished satisfactorily with straightening vanes, it would be too costly for the common centrifugal separaors. However, a simple device for accomplishing this s a cylindrical hood, the edge of which extends over he outside of the collector drum as shown in FIG. 2.

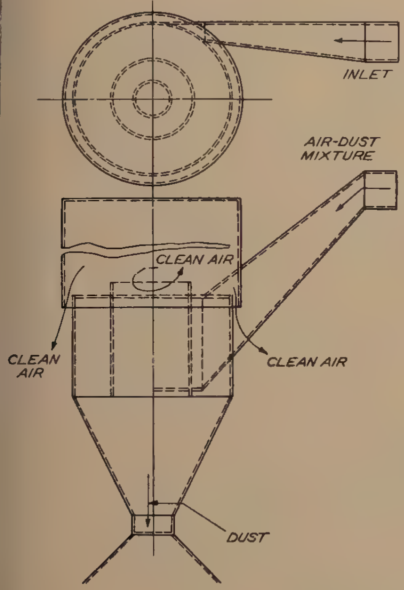


Fig. 2. Centrifugal separator with pressure-recovery devices

In such a device, the rotating flow is slowly dissipated and the velocity of air in the gap between the drum of the separator and the lower edge of the cylindrical hood is low. In the foregoing example, an additional pressure reduction of 0.15 in. water could be achieved. This would result in a saving of 0.8 hp. Together with the elimination of wasted power at the inlet, the total power saving would be 5.6 hp, or a reduction in the power consumption of 75 percent (from 7.5 hp to 1.9 hp) at equal dust-separating efficiency.

VORTEX COLLECTORS

In a vortex collector, the shell is designed to create a vortex.(6) A modern, high-efficiency separator is characterized by its long slender form(7), as shown in FIG. 3. The principle of its operation is the same as that of the centrifugal separator. The air enters tangentially into the long, cylindrical body. The dust settles out at its opposite end while the rotating air reverses the axial direction of its flow and leaves the cylinder close to the inlet through an inner cylinder which is arranged coaxially with the main cylinder. Because of the high partial vacuum formed by the vortex at the axis of the separator, the dust hopper must be sealed carefully against the atmosphere(7) unless the static pressure of the gas at the inlet is more than 14 psi above atmospheric pressure, so that the absolute pressure in the center line of the dust hopper is more than 15 psi.

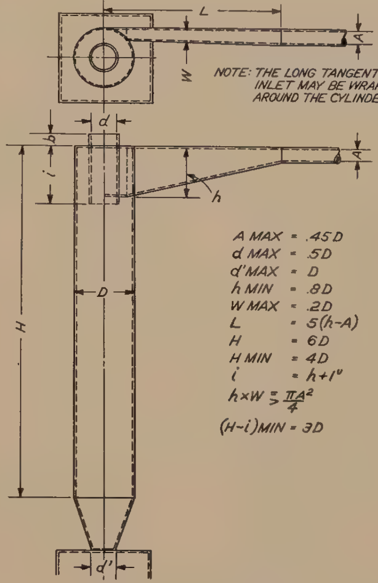


Fig. 3. Vortex collector

The superior separating quality of this type of collector, which attains a separation of 91 percent of carbon dust as fine as 1.0 micron and of 99 percent of limestone dust of a fineness of approximately 10 microns, is directly dependent upon the existence of a strong vortex.(7)(8)

Originally it was believed that, according to the mathematical expressions for the balance of centrifugal forces and drag forces, the diameter of the separating cylinder should be a minimum.(9) However, it was soon discovered by test that there is no limitation for this diameter.(6) On the contrary, large-diameter separators show a higher separation efficiency than small ones. It was learned also that the ability to separate fine dust from gas is not dependent upon the diameter of the vessel, but upon the presence of a vortex.

Numerous tests proved that, when the vortex was destroyed by guide vanes, wires, rods, or other mechanical objects in the slender cylindrical body of the collector, the air-flow pattern changed into a rotating flow of more or less equal angular velocity. When this occurred, the efficiency of dust separation decreased to the level of ordinary centrifugal separators. This characteristic is an important factor in the solution of the problem of reducing the pressure drop. Of course, if the vortex were to be changed to a flow of constant angular velocity, the pressure drop would be decreased considerably(1), with a corresponding loss of efficiency; hence, means must be sought to reduce the pressure drop across the complete system without interfering with the vortex.

Again, as with centrifugal separators, the pressure drop can be decreased at both the inlet and at the outlet of vortex collectors.

INLET DEVICES

Tests have shown that the formation of a vortex with high tangential velocities at the center is independent of the tangential velocity of rotating air close to the wall of the cylinder.(10) The inlet velocity does not have to be higher than that necessary to provide a kinetic energy which is sufficient to overcome the friction both of the gas against the walls and of the vortex. This furnishes the principal source and easiest method of pressure-drop reduction. It is only necessary to reduce the velocity in the inlet duct in such a manner that the decrease of kinetic energy at the inlet is properly converted into a corresponding increase of static pressure.

This can be attained by a gradual enlargement of the cross-section of the duct which carries the dust-air mixture into the collector.(5) The velocity in this duct is determined by considerations of the pneumatic transportation of dust. When high conveying velocities are employed, the pressure recovery at the inlet can be substantial. The enlarged area of the inlet duct must be rectangular at the intersection of the duct and the cylinder of the collector. To prevent any interference with the separation, the dimension W in FIG. 3 must not be altered. However, the height h (FIG. 3) of the inlet can be changed to suit the recovery if only the height $(H-i)$ below the lower edge of the rectangular inlet (FIG. 3) is kept constant. Therefore, such a pressure-recovery device at the inlet will increase the height of the collector. In addition, it is necessary to install the inlet pipe inclining downwards into the collector to prevent an accumulation of dust due to the reduction in velocity as described for the centrifugal separator. Again, the pressure recovery is twofold. One part is due to the conversion of kinetic pressure into static pressure caused by the gradually enlarged inlet duct. The second part is due to the decreased pressure drop of a vortex of reduced peripheral velocity.(1)

OUTLET DEVICES

Means of reducing the pressure drop of the complete system by special devices at the clean-air outlet of the collector are numerous. However, only a few are of practical simplicity and still provide a substantial pressure-drop reduction. There follows a description of the results of a series of tests made for the purpose of demonstrating, in general, the magnitude of the reduction which may be expected. These tests also show that some of the devices used commercially are not only useless, but that they actually increase the pressure drop.

A vortex collector was built as shown in FIG. 4. When the tests were run without dust, the dust hopper was replaced by an air-tight cover. The dust hopper was used only in runs where the pressure recovery was checked by a dust-separation test. The inner cylinder had an opening of 4½-in. diameter and was so constructed that various outlet assemblies could be attached to its upper flange. The apparatus as shown had an over-all static pressure drop of "unity" between the 1-in. by 12-in. inlet area to the outside cylinder and atmospheric pressure at the unit flow.

The parts to be attached to the standard test collector can be classified as those which discharge the clean air to open atmosphere and those which deliver it to ducts.

Results obtained with the open-discharge devices will be described first. The simplest of such attachments is a cone, as shown in FIG. 5. It was held rigidly from above and located coaxially with the vortex cylinder, with the lower or 1½-in. diameter flush with the upper 4½-in. diameter outlet shown in FIG. 4. The pressure drop reduction was 4 percent from unity.

FIG. 6 shows a cone which is a continuation of the upper end of the inner cylinder (FIG. 4). It is designed to fit around the upper part of the outside cylinder by means of the collar at the lower end (FIG. 6). The assembly of such a cone does not reduce the pressure drop. If the angle of the cone is larger than the natural divergence of the vortex escaping from the inner 4½-in. diameter hole, this cone does not interfere with the air flow, which results in a static pressure drop of unity. However, if the angle is smaller, the pressure across the system will be increased.

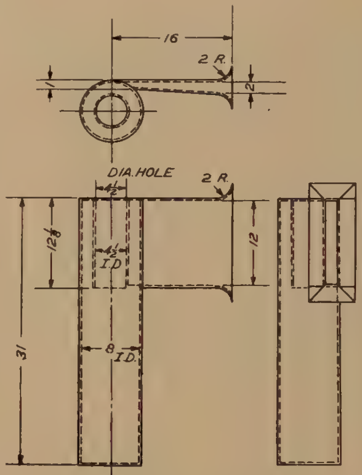


Fig. 4. Test vortex collector

FIG. 7 illustrates the assembly of the inner cone (FIG. 5) in the outer cone (FIG. 6). The upper end of the inner cone carries a horizontal collar (FIG. 8) which can be attached to the inner cone in such a manner that its height is adjustable. The upper end of the outer cone also has a horizontal collar, as shown in FIGS. 6 and 7. The combination of the two cones permits a variation of the distance between them. Obviously, the recovery of static pressure is a maximum with a certain annular space between the two cones and at a certain vertical distance between the two horizontal collars. This was attained at the dimensions shown in FIG. 7, and amounted to 34 percent from unity.

Another solution of a free discharge with pressure recovery is based upon the concept of converting the spinning kinetic energy into axial kinetic energy in an annular ring, and then changing this kinetic energy into static pressure by decreasing the flow velocity in a cylinder or in a cone as shown in FIG. 9. The lower part of this device, which contained the straightening vanes and which could be attached to the outer cylinder by means of a collar, was designed as shown in FIG. 10. There were 16 straightening vanes 2 in. wide, 2 in. long and $\frac{1}{16}$ in. thick curved into a circular arc of 36 deg. They could be attached to the vane cone (FIG. 10) by means of studs and nuts which also permitted angular adjustment. The central opening was closed by means of a large machine bolt and the outlines streamlined by a plastic mass as shown. It was possible to assemble a 2-in. diameter cylinder from the machine bolt vertically downward to a point 1¼ in. within the inner cylinder of the collector (FIG. 9). Above the vane cone (FIG. 10) the outlet cylinder (FIG. 11) or the outlet cone (FIG. 12) could be attached. Calling the angle between the connecting line of the edges of the bent blades with a horizontal line the blade angle, there must be a maximum pressure recovery for a certain combination of blade angles and number of blades. This optimum was obtained by test. With 16 vanes, it existed at a blade angle of 80 deg., without any outlet attachment of cylinder or cone and without the central 2-in. diameter cylinder. The recovery of static pressure was only 10 percent from unity.

A maximum static-pressure recovery of 24 percent from unity was attained with four vanes at a blade angle of 72 deg with the outlet cone (FIG. 12) and the inner 2-in. diameter cylinder (FIG. 9), which reaches 1¼ in. deep into the separator. The outlet cone (FIG. 12) contributed 7 percent of this recovery. The outlet cylinder (FIG. 11) replacing the outlet cone (FIG. 12) adds 6 percent to the static-pressure recovery of the set of four vanes as described.

While all the previous methods of regaining the static pressure retained the same percentage at varying air flow, the method of applying turning vanes is sensitive to the amount of air flow. It must be designed for one particular air flow only, and should not be used in installations of varying air flow. In this test, the maximum recovery of static pressure was attained at an air flow of 250 cfm.

It is more difficult to accomplish static-pressure recovery from a vortex collector the outlet of which is connected to a duct instead of discharging direct to the atmosphere.

Generally, the upper rim of the inner cylinder is provided with a reducer fitting to attain a practical

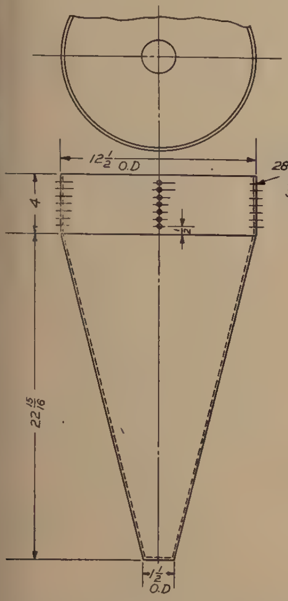


Fig. 5. Inner cone for pressure reduction with open discharge

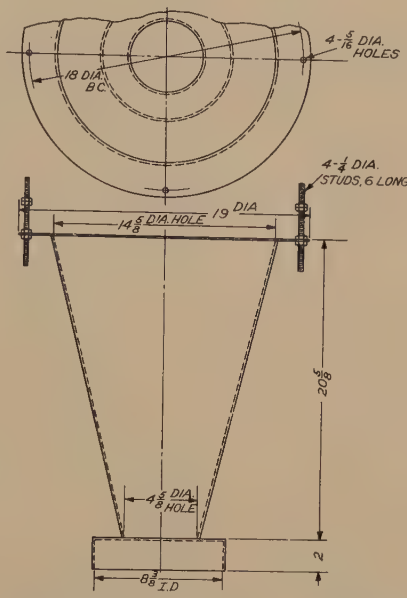


Fig. 6. Outer cone for pressure reduction with open discharge

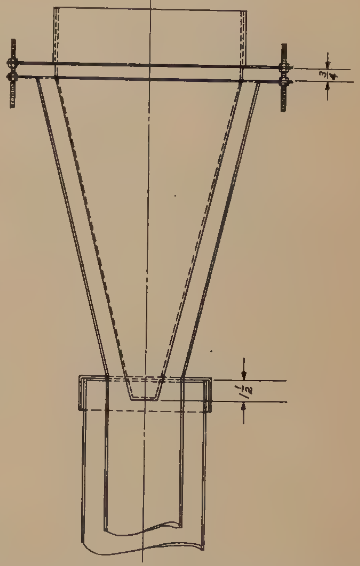


Fig. 7. Double-cone assembly for open discharge

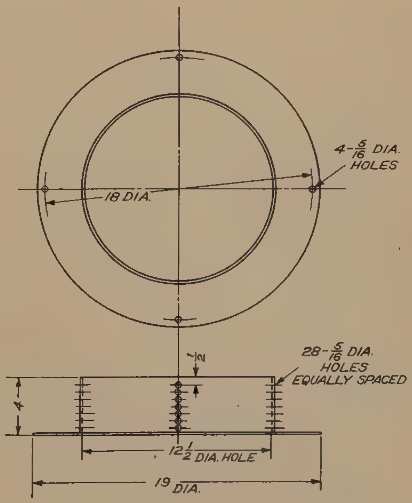


Fig. 8. Horizontal collar for cones

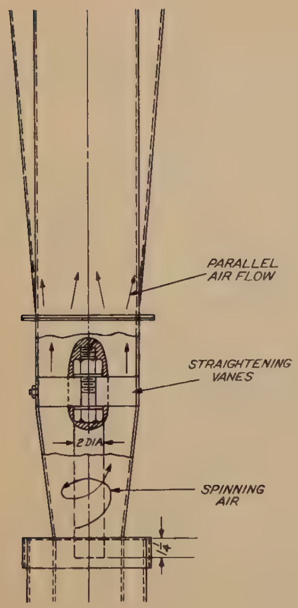


Fig. 9. Device for straightening air flow in open discharge

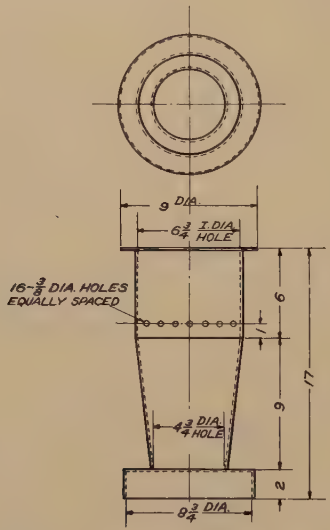


Fig. 10. Vane cone for device shown in Fig. 9

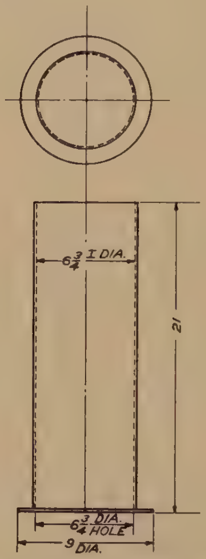


Fig. 11. Outlet cylinder for device shown in Fig. 9

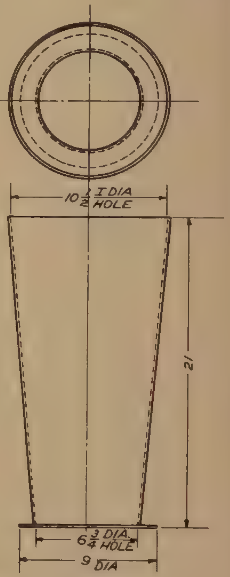


Fig. 12. Outlet cone for device shown in Fig. 9

pipe size. Pipe bends follow in the line without regard to the high pressure drop which they cause.

Apparently a logical way to guide the rotating gases from the inner cylinder into a duct is to assemble a cylinder with a tangential outlet on the top of the collector as shown in Fig. 13. It was believed that the diverging tangential outlet would convert some of the spinning kinetic energy into static pressure, which would mean a corresponding amount of pressure-drop reduction. The cylinder (Fig. 13) could be assembled over the upper part of the outside cylinder shown in Fig. 4. Three different variations from Fig. 13 were also tested. One was a cylinder with a tangential outlet opening of only 1 by 9 in. instead of 1 by 12 in. The second consisted of a cylinder which was 19 in. high instead of 16 in., but which had the original 1 by 12-in. tangential outlet. In the third, the tangential outlet of the second variation was removed so that the cylinder wall had an opening of 1 by 12 in. only.

All four designs required more than "unity" static pressure across the system, "unity" being the static pressure between the cylinder inlet and outlet at the same amount of air flow through the collector, but without any additions, as shown in Fig. 4. The collector, with an outlet as shown in Fig. 13, had a static-pressure drop of 7.5 percent above unity. The pressure drop across the first variation with a 1-in. by 9-in. tangential outlet exceeded the unity pressure by 17 percent. The pressure drop across the second variation, with a 19-in. high cylinder and a 1 by 12-in. tangential outlet, exceeded the unity pressure by 5 percent. The third variation, without any outlet duct, was the best design; however, the static pressure drop across it was still 4 percent higher than the unity pressure. Fig. 14 shows a comparison of the effect of adding the outlet as described.

A slight change of the design provided a reduction of the pressure drop from unity. It was only necessary to assemble the tangential outlet, as shown on Fig. 13, close to the bottom plate of the 8-in. diameter cylinder instead of close to the top plate.(11)

The cross-section area of the tangential outlet at the bottom was the same as that of the pipe connected to the reducer fitting on top of a vortex collector without the recovery device. The pressure recovery was 33 percent. Compared with a vortex collector without this device where the reduced pipe was followed by an

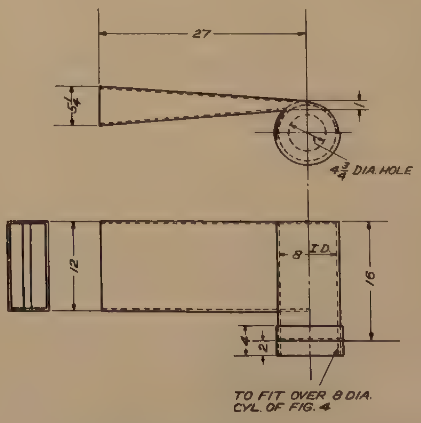


Fig. 13. Cylinder with tangential outlet for discharge into a duct

elbow of the same cross-sectional area, the collector with the pressure-recovery device showed a pressure recovery of 47 percent. A diagrammatic arrangement of these collectors and their pressure drops is given in Fig. 15.

Generally, the clean gases from vortex collectors are piped off horizontally so that, in all such cases, a pressure-drop reduction of 47 percent can be obtained. However, in cases where the clean gases are led off vertically, and it is necessary to attach an elbow to the tangential outlet of the recovery cylinder, the reduction of pressure drop is arrived at as follows: The 90-deg bend can be made rectangular with the same inside dimensions as the cross-section of the tangential horizontal outlet. Since the flow is parallel and not spinning, it is possible to insert splitters in this bend. This will decrease the pressure recovery by only 2 percent.

With the vertical bend, the reduction of pressure drop is still 31 percent from the pressure drop across a vortex collector with a reducer fitting, but without an elbow at its outlet. The vortex collector without recovery device and with a free discharge without any pipe attachments has 3 percent more pressure drop across the system than one with a recovery device and a tangential outlet.

Even though the outlet duct cross-section area is only 36 percent of the area of the inner cylinder of the free discharge collector, the pressure drop is less with the recovery cylinder than with an open discharge.

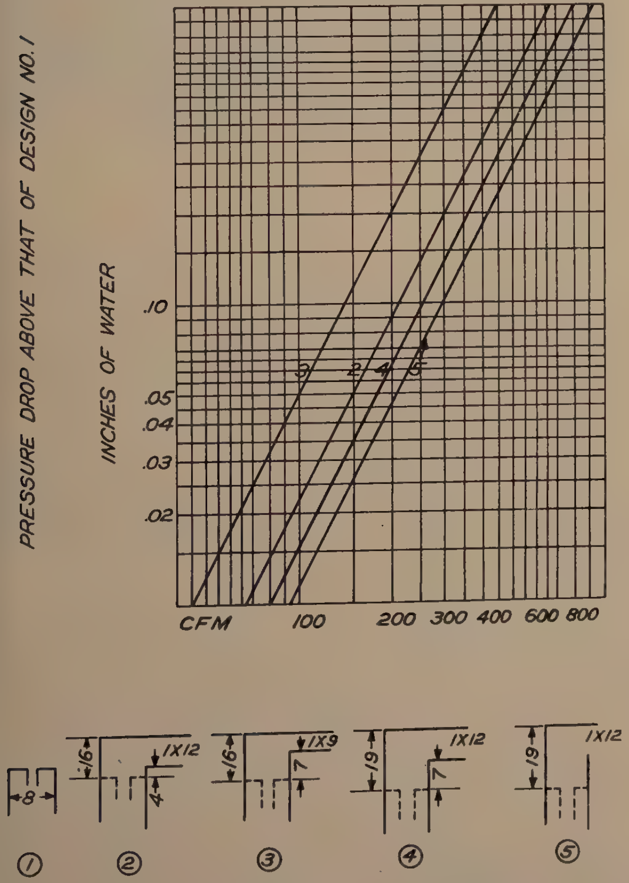
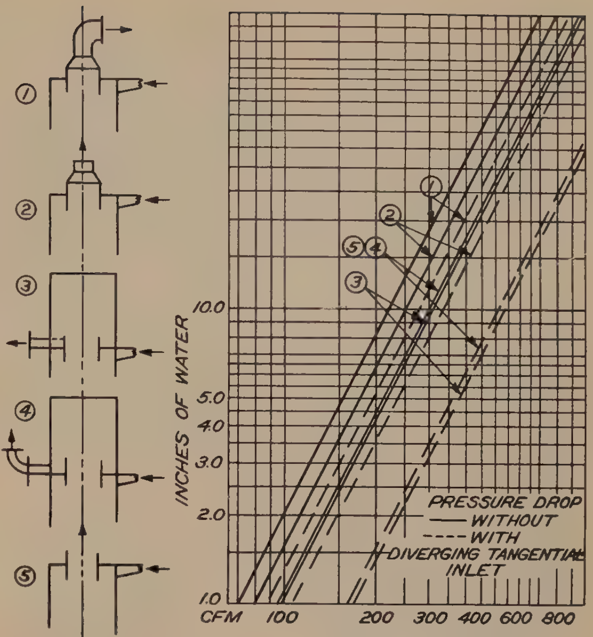


Fig. 14. Increase of pressure drop due to the use of illustrated types of recovery drums compared to collector without recovery drum, arrangement (1)



PRESSURE DROP ACROSS SEPARATORS INS. WATER

DESIGN NO.	WITHOUT DIVERGING TANGENTIAL INLET 1) VEL.HDS	WITHOUT DIVERGING TANGENTIAL INLET AT 275 CFM	WITH DIVERGING TANGENTIAL INLET 1) VEL.HDS	WITH DIVERGING TANGENTIAL INLET AT 275 CFM
1	1.43	15 3/8	.92	9 7/8
2	1.12	12 1/8	.61	6 5/8
3	.75	8 1/8	.24	2 5/8
4	.78	8 3/8	.27	2 7/8
5	.78	8 3/8	.27	2 7/8

1) VELOCITY HEAD MEASURED AT INLET TO OUTER CYLINDER

Fig. 15. Comparison of pressure drop across vortex collectors with various outlet attachments

Of course, the open discharge through the inner cylinder should be compared with an open discharge of the recovery apparatus. Instead of a tangential outlet, the discharge can be made in the form of a ring slot at the bottom end of the outer cylinder of the recovery device, which has the same area as the area of the inner cylinder. With an open discharge, the recovery cylinder can furnish a pressure-drop reduction of 15 percent from the value required by a design with an open discharge through the inner cylinder of the same outlet area.

Additional tests were made to discover whether a cone inserted into the inner cylinder and surrounded by a pressure-recovery cylinder would increase the pressure recovery. The assembly is shown in Fig. 16. The improvement was negligible, amounting to only 5 percent.

The influence of the various devices upon the magnitude of the pressure-drop reduction is tabulated in Fig. 15.

Summarizing the results of these tests of vortex-collector pressure-recovery devices, it can be stated that collectors which discharge the clean air into open atmosphere can be provided with pressure-recovery devices which reduce the pressure drop across the system by a maximum of 34 percent. This holds for the assembly of an inner and an outer cone at the outlet of the inner cylinder, similar to the arrangements shown in Figs. 6 and 7. Vortex collectors which discharge

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the clean air into ducts can be substantially improved by assembling a cylindrical drum with a tangential outlet at the bottom, similar to that shown in FIG. 16. The reduction of pressure drop without the cone will be from 47 percent to 48 percent depending upon the diameter and the height of the recovery cylinder. If the cone is inserted, as shown in FIG. 16, the reduction of pressure drop increases to 49 percent.

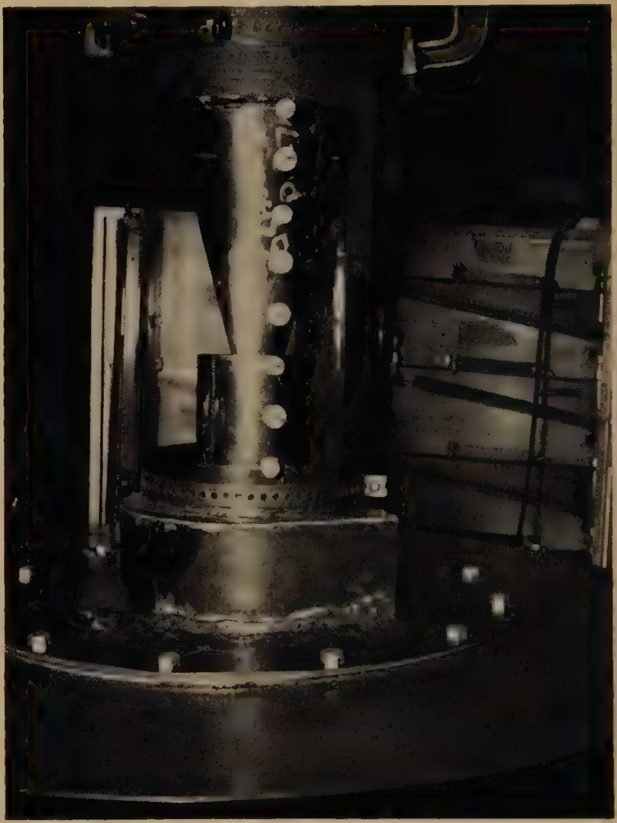

Fig. 16. Test assembly of vortex collector

The devices for pressure recovery used on vortex collectors were considered without regard to any gain from the tangential inlet. Such a method of pressure recovery is possible only if the accumulation of dust in the inlet pipe can be prevented. The vortex collector shown in FIG. 4 did not make use of such a device; but it was tested in the apparatus shown in FIGS. 15 and 16. The 1¾-in. inlet pipe was gradually enlarged, within a length of 2½ ft, to an opening of 8 in. by ⅜ in. The reconversion of kinetic energy into static pressure in such a duct is 5½ in. water at a flow of 275 cfm. The ratio of the inlet and outlet areas of the duct indicate a theoretical static-pressure recovery of 5.9 in. water. The difference of 0.4 in. water was lost in turbulence.

Since every pressure drop that was observed in the tests described was taken between the inlet area at the outer cylinder and free atmosphere, it can be further reduced by deducting a pressure recovery of 5½ inches water at an air flow of 275 cfm due to the influence of the tangential inlet. The pressures at the inlet to the pipe and at the inlet to the outer cylinder were measured simultaneously.

TABLE I

PRESSURE RECOVERY IN VORTEX-COLLECTOR STRUCTURE

Design	Percent Recovery in Pressure Drop	
	Between outer cylinder and atmosphere	Between tangential inlet and atmosphere
Standard 3-inch elbow	0	35
Recovery drum, 3-inch outlet	48	83
Standard vertical 3-inch outlet	0	45
Recovery drum, 3-inch outlet with 3-inch vertical upturn	31	76

Table I shows that a combination of pressure recovery devices consisting of a recovery drum and a diverging tangential inlet can reduce the pressure drop across the system by approximately 80 per cent.

The result of the tests reveals that the flow in the tangential outlet duct at the bottom of the recovery cylinder is straight and not rotating. Therefore, additional reduction of pressure drop can be achieved by gradually enlarging this outlet. In discharging clean air directly into the atmosphere, the ring slot at the bottom of the wall of the recovery cylinder can be extended into two parallel flanges which likewise recover additional pressure drop.

CONCLUSION

The pressure drop across cyclone dust collectors can be reduced by relatively simple means. A recovery of 75 percent can be attained on centrifugal separators by employing gradually enlarged tangential inlets together with cylindrical hoods at the outlet. The pressure drop across vortex collectors can be reduced by approximately 80 percent by using diverging inlets and recovery drums at the outlet which discharge clean air into ducts. If the vortex collectors discharge the air into the atmosphere, the pressure drop across them can be decreased by 34 percent with two concentric cones at the outlets, and by amounts up to 80 percent when these cones are combined with a diverging tangential inlet.

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(11)U.S. Patent, 2,424,122—Schneider 1947.

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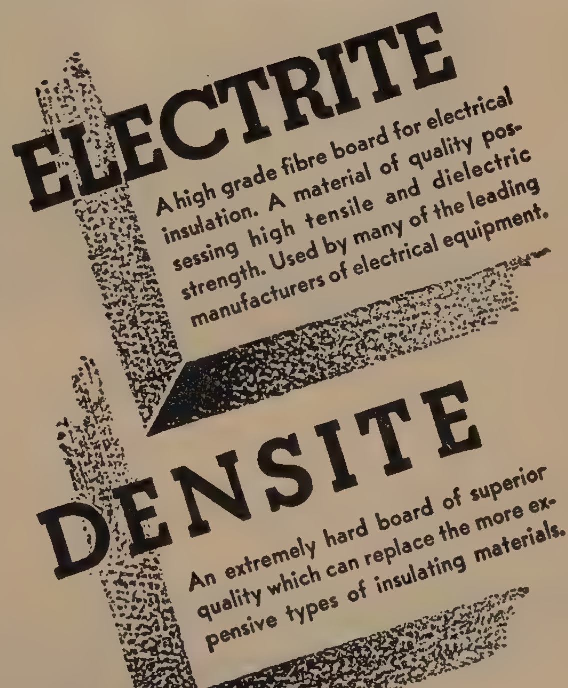
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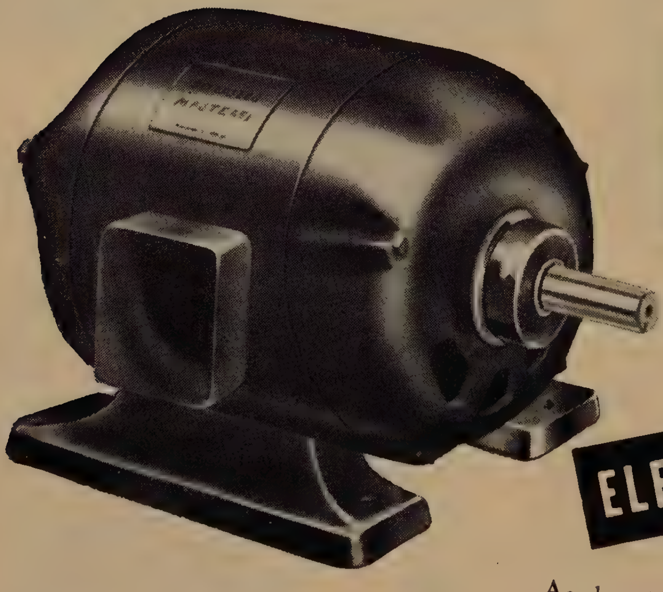

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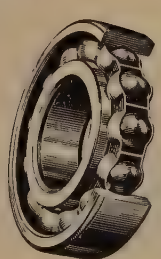

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THE AMPLISTAT AND ITS APPLICATION . . Part I

New type of static power control for two classes of service: one for large-signal and one for small-signal amplifications. Various features of application to the large-signal circuits

By H. M. OGLE
General Engineering and Consulting Laboratory
General Electric Company

H. Malcolm Ogle

A NEW static power-control device now finding many applications in industry is the amplistat. This device can be adapted to the control of most electric equipment, and provides operation at low cost, with reduced maintenance, and with a long life expectancy.

The amplistat combines a saturable-core reactor and a rectifier. The former is a device somewhat resembling a transformer, with several windings linking one or more laminated iron cores. It differs from the transformer in that the core is designed to be operated in the region of magnetic saturation during part of each cycle. The rectifier used to make up the amplistat can, theoretically, be of any type, but the most common now in use are selenium and germanium crystal rectifiers.

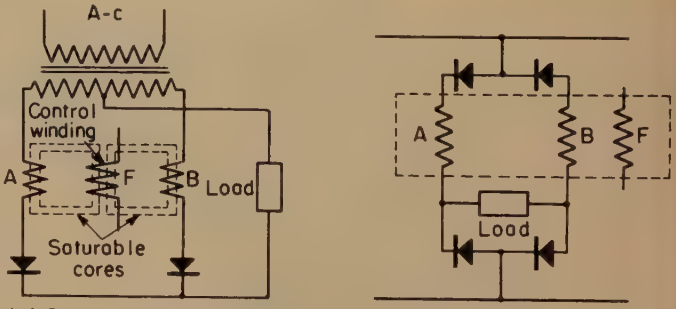
Saturable-core reactors have been used by themselves for power-control devices, although their inherent qualities of low amplification and slow response have restricted their use. The amplistat, however, overcomes both of these limitations and definitely acquires broad usefulness as a control device.

Amplistats can be used wherever electrical signals of low or moderate frequencies are to be amplified. For some applications they are used because they have no warm-up time. In some cases they are selected because of their long life and sturdy construction, or because they are the lightest-weight equipment to do a given job. Most applications, however, are the result of a combination of these or other features such as the ability to match impedances, or the electrical isolation of the input circuit. Amplistats, in general, are easy to apply, and provide a flexible tool for the circuit designer.

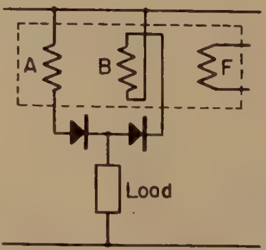
It is convenient to consider amplistats in two general classifications: one for large-signal amplification, the other for small-signal amplification. The dividing line between these two classifications is that point at which the signal becomes so large that the efficiency of the amplifier becomes important. Design considerations for each of these classifications must be studied separately. If multistage amplifiers are being designed, coupling from one stage to another introduces other factors which must be taken into account. Regulating systems present unique problems and require, in some cases, special devices to provide the necessary references and stabilizing means. Some special circuit arrangements are possible to assist in designing limit circuits or computing circuits. With an understanding of these considerations it is a simple matter to apply an amplistat to any specific job.

LARGE-SIGNAL AMPLIFICATION

FIG. 1 shows several circuits commonly used for large-signal amplification. The center tap circuit shown in FIG. 1(a) is perhaps the easiest to understand. It consists of a center-tapped power transformer; two saturable cores, each with its own a-c winding; and two rectifiers, one in series with each a-c winding.



(a) Center tap amplistat (b) Bridge amplistat



(c) A-c amplistat

Fig. 1. Basic amplistat circuits

Each rectifier is connected to the load, which is in turn connected with the center tap of the power transformer. The control winding links both saturable cores. The blocking rectifiers permit only unidirectional cur-

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

rent flow in the a-c windings, and each core controls the load current on alternate half-cycles.

At the start of the voltage cycle there will be no current flowing in one a-c winding. As the voltage builds up in a positive direction, current will begin to flow through the rectifier and into the load. This current is limited to a very small value by the large inductance of the winding, which continues to be large only so long as the core can store flux (that is, has high permeability). When the core becomes saturated the a-c windings no longer limit the current in the circuit, and the current will immediately jump to a large value. During the remainder of the cycle the current is limited by the load resistance. By varying the current through the control winding, the firing point of the reactor (and therefore the average load current) can be controlled. Note that the control current can influence the load current only during each half-cycle before the firing point.

The circuits shown in Figs. 1(b) and 1(c) operate in exactly the same manner. The bridge circuit in Fig. 1(b) also gives a d-c output by substituting two more rectifiers in place of the center-tapped transformer. The circuit in Fig. 1(c) gives an a-c output into its load.

The current wave shape in the load of all these circuits is quite irregular. For this reason the current heating effect (or rms value) is almost twice the average value. This is an important point to remember when heating effects are to be considered. If an amplistat is to be used to light an incandescent bulb or a heating device, it can be expected to deliver almost twice the power output that it could put into a machine field, where average current is the important consideration.

Inductive Loads

Inductive loads pose special problems. Because the amplistat limits current by inductance, it will tend to lose control of the current when used in circuits which present highly inductive loads. There are three means of overcoming this problem. One is to use a large amount of series resistance, which will improve the power factor of the load and eliminate the problem. This is of course a very inefficient solution and is suitable only for special cases where this inefficiency can be tolerated.

Another solution is to connect a capacitor across the load. This also improves the power factor and eliminates the problem. In many cases, however, the capacitor required will be very large, and this method would be unacceptable for economic reasons.

The circuit shown in Fig. 2 will also alleviate the inductive condition. In this circuit, a rectifier is used to dissipate the stored energy in the inductive load and thereby prevent the inductance of the load from upsetting the controlling action of the amplistat. By placing a rectifier across the load a return path is provided for the inductive discharge.

The bridge amplistat, Fig. 1(b), provides inherently a relatively high-resistance return path and can often be used with slightly inductive loads without a commutating rectifier. With highly inductive loads, a commutating rectifier is desirable even with this circuit.

Snap-action Circuits

The instability of amplistats with inductive loads is sometimes used to produce snap-action circuits. In these circuits the output current will have two possible values for a single value of control current; by a small change in the control circuit the load current is made to snap from one value to another. This type of action is particularly desirable when relays are to be replaced with (or driven by) amplistats.

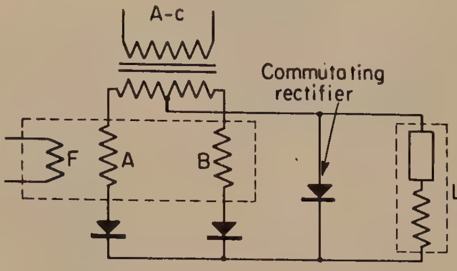

Fig. 2. Commutating rectifier for inductive loads

Another way of obtaining snap action is to take a small portion of the output of an amplistat and feed it back into a control winding. If the polarity of this winding is such as to give positive feedback and a sufficient amount of current is fed back, a snap action will be obtained. This type of circuit can be used with success with any type of load, as it is not dependent upon the load to produce the snap action.

Motor Control

One of the major problems of amplistat application is that of motor control. The simplest type of motor control is that shown in Fig. 3—a simple bridge amplistat used to supply the field of a d-c motor. This can be used wherever a small range of motor speed is all that is desired. A very small amount of energy is required with this system to vary the motor speed throughout its range; some means must be provided, however, to insure a strong field during starting of the motor. A centrifugal switch, set to drop out at minimum motor speed, could be arranged as shown in Fig. 3 to provide that function.

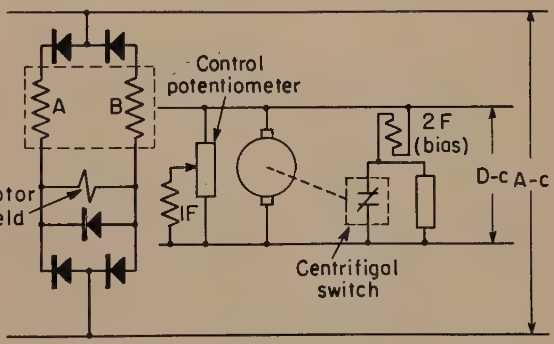

Fig. 3. D-c motor field control

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(Continued from preceding page)

A much wider speed range can be obtained from a d-c motor if armature control is used. Such a control is shown in FIG. 4. In this case the amplistat must be designed to supply the peak current required by the motor armature and must be able to deliver this current into the back emf of the motor when it is operating at full speed. By means of this circuit it is quite possible to get speed ranges up to 100:1 from small d-c machines. The motors should be specially designed for this application in order to reduce losses caused by the a-c components of the amplistat output. In this respect the circuit is very similar to thyratron motor-control circuits. In fact, motors designed for thyratron circuits are suitable for amplistat circuit applications.

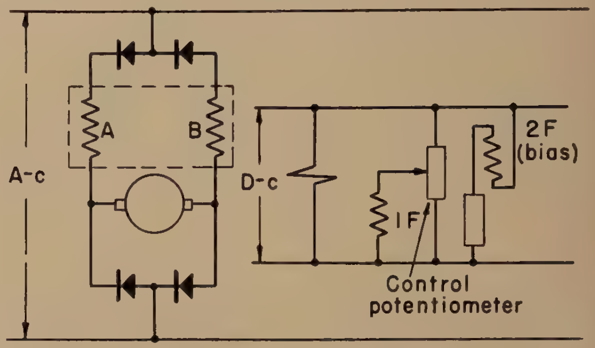

Fig. 4. D-c motor armature control

With either type of circuit, auxiliary means must be provided to reverse the motors. For some applications this can be done with contactors, but in many cases—as, for example, in servo systems—this would not be a practical solution. Two bridge circuits can be so arranged that one will drive the motor forward and the other will drive it backward. Unfortunately, when the motor is running forward, the back emf of the armature causes the backward-driving bridge to conduct and results in excessive circulating current.

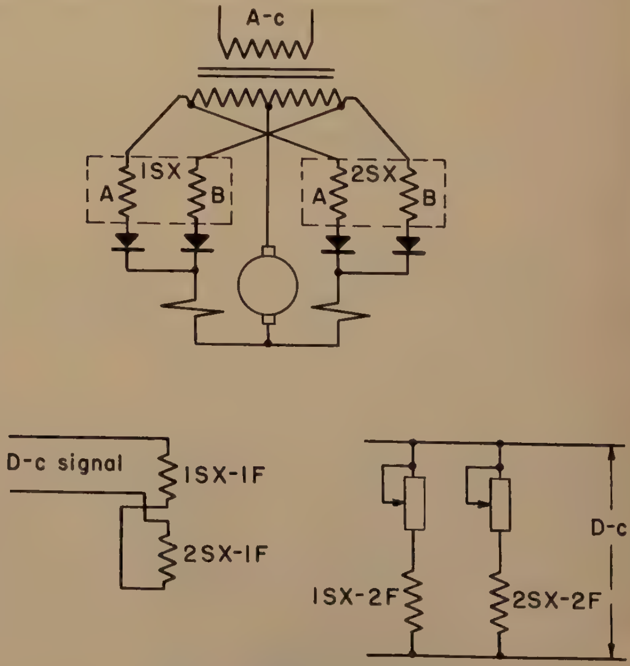

Fig. 5. Split-field motor control

The circuit shown in FIG. 5 overcomes these difficulties by the use of a split-series field motor. Two amplistats are used, each one supplying current through one half of the split-series field. The amplistat circuits have a common return, fed through the motor armature, and bias windings are provided so that each amplistat current can be set to the desired zero signal value. The signal windings are so connected that an increase in signal of one polarity will cause one amplistat output to increase and the other to decrease. In this way a resultant field flux will be established, which, operating in conjunction with the armature current, will cause the motor to produce torque acting in one direction.

By reversing the polarity of the signal this torque can be reversed so that either direction of motor rotation can be obtained without resorting to any switching circuits. The zero signal current in such a circuit is usually set to a low value so as to reduce motor heating when it is not rotating. An increasing signal will not only produce a resultant field but will also raise the total value of armature current. This happens because the forward-acting amplistat can increase its output more than the backward-acting amplistat can decrease its output. Thus the maximum torque of the motor can be utilized without an excessive rise in temperature of either the armature or the commutator.

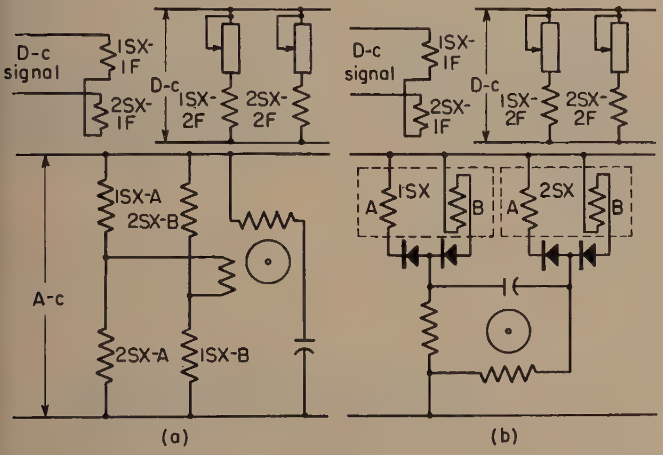

Fig. 6. A-c motor control circuits

Servo Applications

For servo applications it is frequently desired to control two-phase induction motors. Two circuits which can be used for this purpose are shown in FIG. 6. In this case it is necessary to have the current in one of the motor windings approximately 90 degrees out of phase with the current in the other winding. Torque can be varied by adjusting the magnitude of the current in either or both phases. In the circuit in FIG. 6(a) one phase remains fixed at all times, while the current through the other phase is varied. In the circuit in FIG. 6(b) the magnitude of the current in both phases varies in accordance with the signal.

(To be continued)

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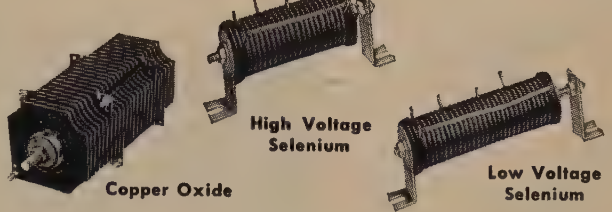

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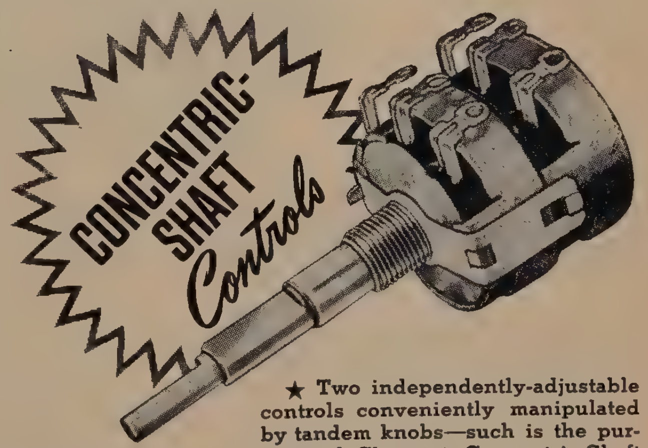

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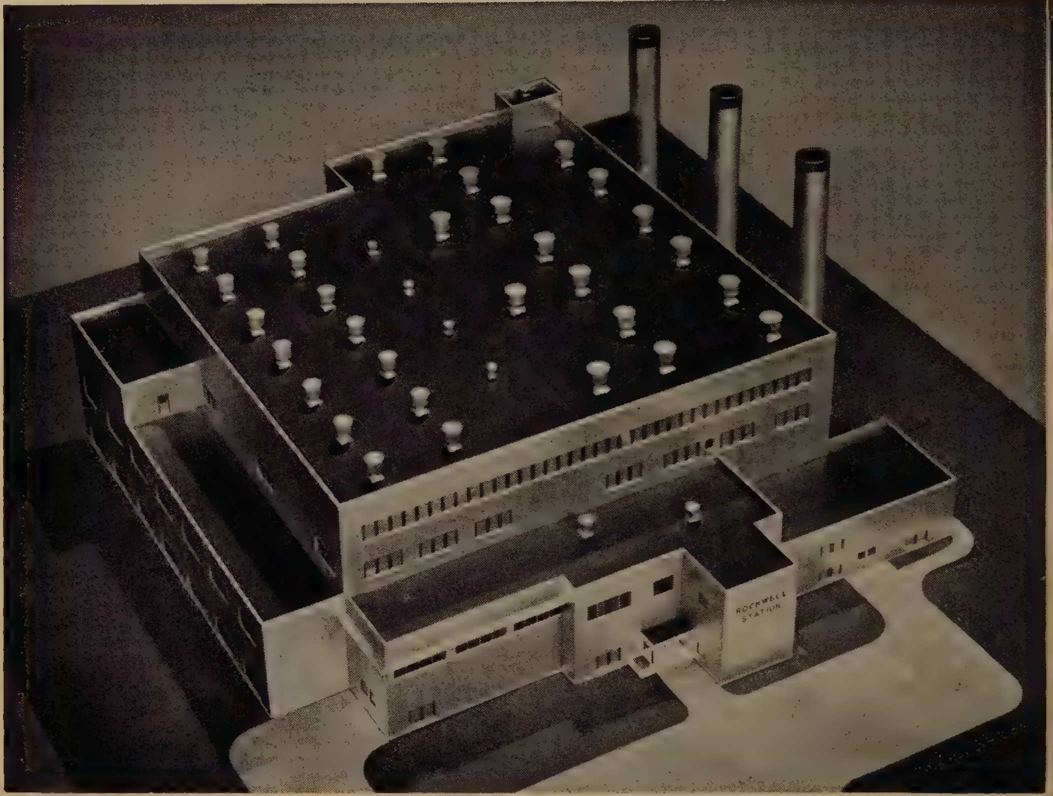

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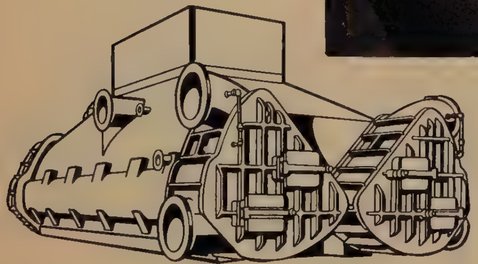

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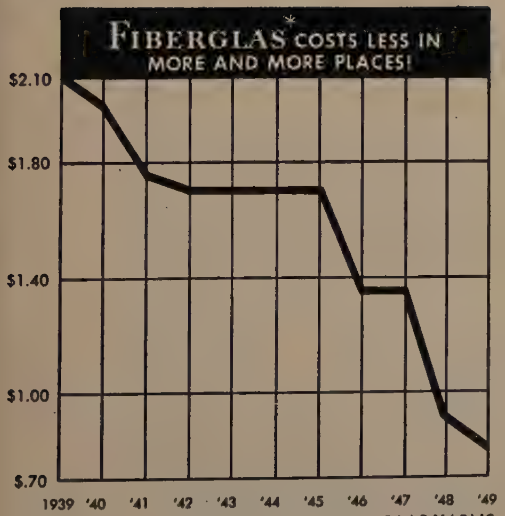

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BACK-UP PROTECTION FOR SYSTEM FAULTS AT THE GENERATOR

Faults cause greater decrease in voltage than normal overloads. Overcurrent relays restrained by generator voltage detect this and so function at the occurrence of a fault only

D C Hoffmann

By D. C. HOFFMANN
Switchgear Divisions, Philadelphia Works
General Electric Company

THE use of fault back-up protection for power transformers and transmission lines has long been recognized as good practice. Back-up relays, for example, will clear a fault in the transformer or line if the primary protection is inoperative for any reason. Back-up protection, however, has not generally been applied directly at the source of fault current—the generator. Hence, there is nothing to clear a fault on the bus, feeder, or other contiguous system elements if the primary protection is inoperative.

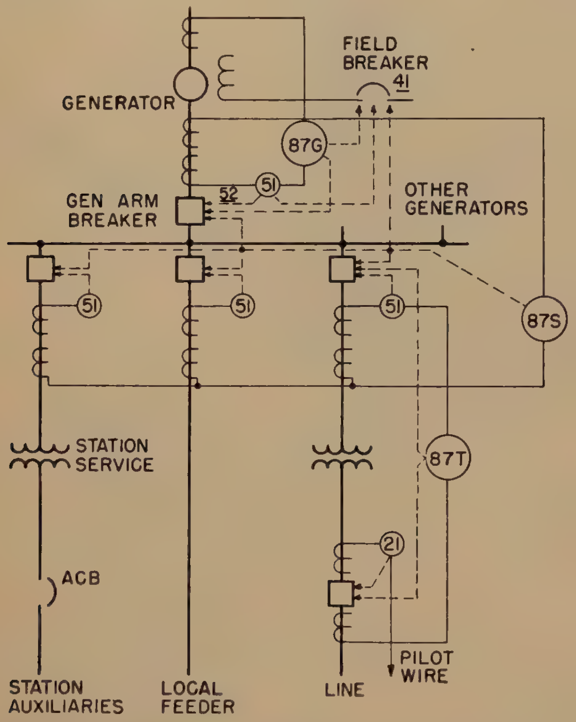

Fig. 1. One-line diagram showing primary and back-up protective devices of typical small generating station

21: Pilot-wire relay
41: Field breaker
51: Overcurrent relays. Serves as back-up protection for line, transformer and feeder
52: Generator armature breaker
87G: Generator differential relay
87S: Switchgear differential relay
87T: Transformer differential relay

In the typical small generating station illustrated by the one-line diagram in Fig. 1, several generators operating in parallel on the station bus supply local feeders, a transmission line, and station auxiliaries. Primary protection may consist of pilot-wire relays *21* for the line, differential relays *87G*, *87S*, and *87T* for the generators, switchgear, and transformer, respectively, and overcurrent relays *51* for the local feeders and the station auxiliary transformer circuit. Back-up protection is provided for line and transformer faults by inverse-time overcurrent relays *51*. Generally, no back-up protection has been applied at the generator for faults on the bus, local feeders, or station service transformer circuits.

Ordinary inverse-time overcurrent relays, with and without instantaneous units, have been used to disconnect generators from the system in case of overcurrent. However, overcurrent relays present a problem in the determination of the proper current and time settings required to obtain the desired protection. If the current setting of the relay is too low, the relay may trip the generator unnecessarily on temporary normal overloads. This might occur if a tie line or one of the other generators is lost unexpectedly. On the other hand, if the current setting is too high, the relay

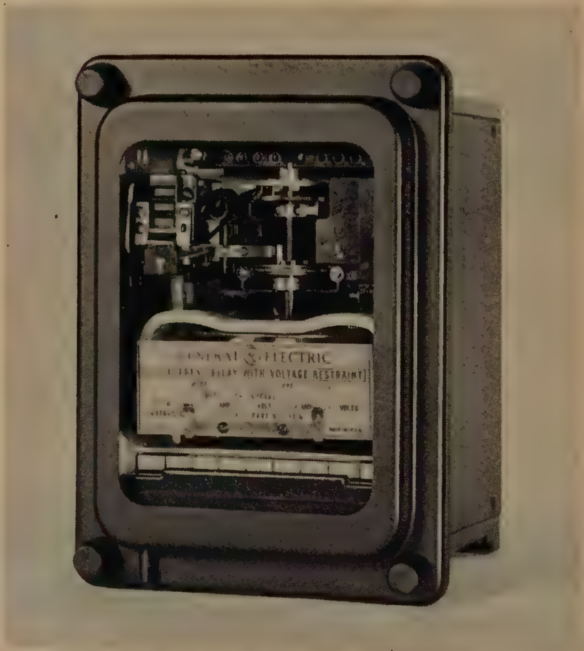

Fig. 2. Single-unit overcurrent relay with voltage restraint which is used as fault back-up protection at the generator

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may not respond at all in the event of a short circuit, because the sustained output current of the generator is limited by its synchronous reactance to a relatively low value. In extreme cases, the sustained short-circuit current may be equal to, or even less than, full-load current as will be explained later.

Since current alone cannot be used safely in most cases to distinguish between faults and normal overloads, an additional quantity must be measured to determine whether the generator should be disconnected from the system. One quantity that can be used is generator voltage. Both faults and normal overloads cause an increase in armature current, but a fault usually causes a greater decrease in voltage than a normal overload. Therefore, an overcurrent relay restrained by generator voltage is capable of determining when a generator should be tripped, by measuring current and voltage at the generator terminals.

SYSTEM FAULT BACK-UP RELAY

A voltage-restrained inverse-time overcurrent relay has been developed for system fault back-up protection at the generator. The relay, Fig. 2, is of the induction-disk-type construction in a drawout case with test facilities. The relay element consists of one current operating magnet and one voltage restraining magnet. The current magnet produces torque tending to close the relay contacts. The restraining magnet and a spiral spring produce torque tending to open the contacts. Permanent magnets acting on the disk provide time delay. A time dial at the top of the disk shaft controls the contact travel. At zero time dial setting the contacts are just closed and at No. 10 setting maximum time delay is obtained. A target and seal-in element is mounted to the left of the disk shaft. The coil is connected in series and the contact in parallel with the main relay contacts so that when the main contacts close, the seal-in element picks up, raising a target into view. The contacts remain closed, and the target remains exposed until released by the external reset button.

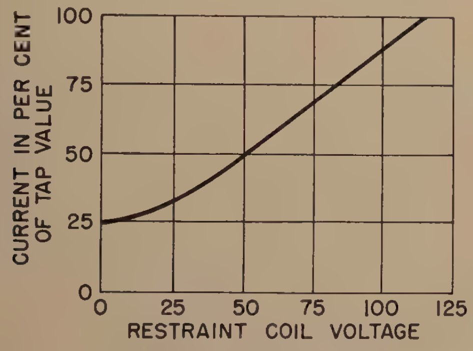
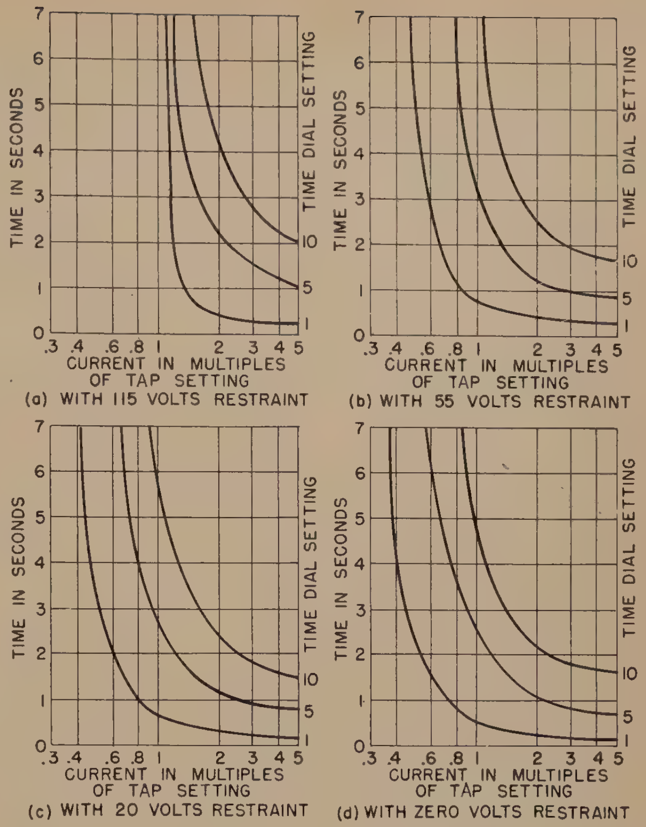


Fig. 3. Typical pick-up characteristic of a voltage-restrained overcurrent relay

The current coil is rated 5 amp and is tapped for 4-5-6-8-10-12-16 amp. Tap value is the pick-up current of the relay (current required to just close the contact) with rated voltage applied to the restraint coil. With zero voltage on the restraint coil, the pick-up current is 25 per cent of tap value. The relation between the pick-up current and restraint voltage is shown in Fig. 3. The time-current characteristics of the relay for several values of restraint voltage are shown in Fig. 4.



(a) WITH 115 VOLTS RESTRAINT

(b) WITH 55 VOLTS RESTRAINT

(c) WITH 20 VOLTS RESTRAINT

(d) WITH ZERO VOLTS RESTRAINT

Fig. 4. Typical time-current characteristics of voltage-restrained overcurrent relay

The current-voltage characteristic of the relay is practically independent of the phase angle between the current and voltage, but it is essential that the restraint voltage be the voltage across the faulted phase so that a true measure of conditions is obtained. Accordingly, three single-phase relays are required per circuit. They are connected as shown in Fig. 5.

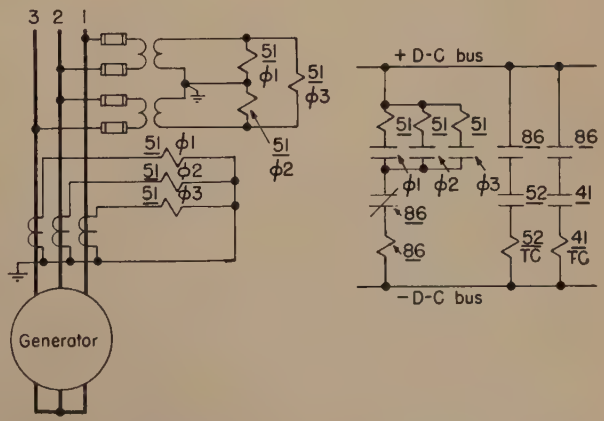


Fig. 5. Connections of voltage-restrained overcurrent relay

41: Field breaker
51: Voltage-restrained overcurrent relays
52: Generator armature breaker
86: Hand-reset lockout relay

GENERATOR VOLTAGE-CURRENT CHARACTERISTICS

Before proceeding with consideration of the current and time settings of the relays, it is well to review some pertinent generator characteristics. The maximum current that a generator will produce initially on short circuit is determined by the subtransient reactance, which ranges all the way from 6 percent for a two-pole turbine-generator to 45 percent for a low-speed waterwheel-generator. Hence, the initial short-circuit current may be as great as 16 times normal. The sustained or steady-state value of short-circuit current is determined by the synchronous reactance of the generator and the characteristics of the regulator and excitation system.

The synchronous reactance value varies with the design of the generator, ranging from 90 percent to 140 percent. The sustained value of short-circuit current may, therefore, be as low as 70 percent of normal for the unregulated generator. If a regulator is in use, it will increase the excitation to the limits of the excitation system, resulting in a sustained value of short-circuit current that may be as high as 275 percent of normal. Since the relay will generally be set for relatively long closing times, the sustained value of current is of greater interest than the initial value, although both must be taken into consideration.

Fig. 6 illustrates the voltage-current characteristics of typical steam turbine-generators with and without voltage regulators. An extreme case is represented by line *AM*, which is for an unregulated generator having 115 percent synchronous reactance with the field current adjusted to the no-load full-voltage value. This would be the situation immediately after the generator has been connected to the bus and before the field excitation has been increased to the normal full-load value. Lines *BN* and *BP* are for the same nonregulated generator with field adjusted for full-load unity power factor and for full-load 0.8 power factor, respectively.

Lines *ABQ* and *ADS* represent the probable limits of a family of characteristic curves of generators with voltage regulators. In this case, the regulator increases the excitation of the generator until the capacity of the excitation system is reached, causing relatively higher values of sustained currents for the same voltage than those that would appear in the unregulated generator.

The current-voltage characteristics of the voltage-restrained overcurrent relay have been included in Fig. 6 to illustrate the relation between relay and generator characteristics. The four relay curves are for tap settings corresponding to 150-200-250-300 percent of normal full-load generator current at normal voltage on the relay restraint coils. The relay will pick up for any value of voltage and current below the characteristic curve. Since the relay curves cross the generator curves at substantially right angles, any effects resulting from possible deviations of the generator curves from the shapes shown are minimized. The shape of the generator curves is influenced by the initial load power factor, the fault circuit impedance power factor, and the magnetic saturation characteristics of the generator.

DETERMINATION OF RELAY CURRENT AND TIME SETTINGS

To illustrate the use of the curves in Fig. 6, assume that the characteristics of the generator under consideration are represented by curve *ACR*. If the relay is set to pick up at 150 percent full-load current, the generator will be tripped when it is carrying more than 135 percent load at 92 percent normal voltage. This would be undesirable from an operating standpoint and unnecessary from a protection standpoint. With a pick-up setting of 300 percent, the trip point is 180 percent current and 60 percent voltage. This, however, probably represents an intolerable condition in most power plants. Between these two extremes is a band, bordered by the 200 percent and 250 percent curves, representing the best compromise between protection and continuity of service for the typical generator with voltage regulator.

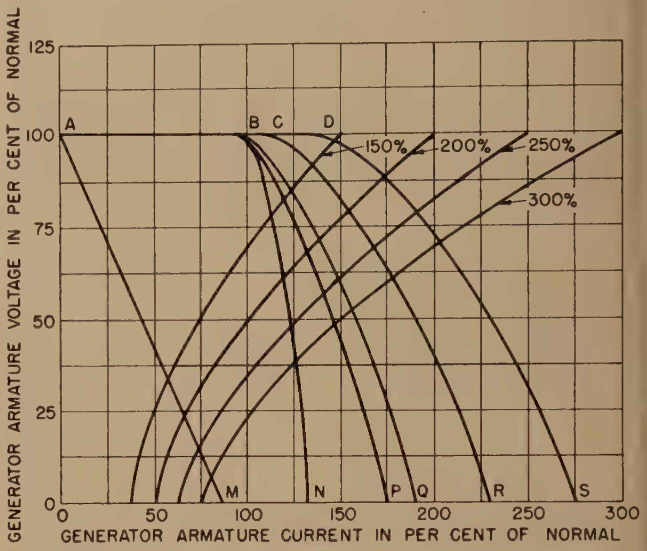


Fig. 6. Generator and relay voltage-current characteristics

Lines *AM* and *BP* represent possible limits of operation for unregulated generators
Lines *ABQ* and *ADS* represent possible limits of operation for regulated generators
Relay curves are for tap settings corresponding to percent normal full-load current at normal voltage

For those few generators that operate without regulators, a lower pick-up setting of the relays seems advisable, because of the lower values of sustained current produced by such generators under fault conditions. A setting between 150 percent and 200 percent full-load current would give about the same protection to the typical unregulated generator as a setting between 200 percent and 250 percent gives the typical regulated generator.

The relay is provided with a 4-to-1 range in current taps to allow some leeway in pick-up setting to meet different conditions and to compensate for a variation of full-load secondary current values that may range between 2.5 and 5 amp. In Fig. 6, the full-load secondary current is assumed to be 4 amp. Hence the 150-200-250-300 percent curves are for the 6-8-10-12 amp taps, respectively. Other current-transformer ratios would cause the relay characteristic curves to shift horizontally with respect to the generator curves.

The proper time setting of the relay is determined in the same way as time settings of other relays in a selective system except that the decrement curves of the generator must be taken into consideration. Since the function of the relay is to back up primary protection in the system, the time setting may of necessity be quite long, but it should not be any longer than necessary to insure selectivity with impedance relays or other overcurrent relays of comparable reach on the system.

In most cases, the tripping operation will occur after the current has decreased to almost the final sustained value; this must be taken into account. The rate of decrease of the generator current from the initial to the final value depends upon the time constant of the generator, its synchronous reactance, and the characteristics of the turbine, regulator, and excitation system. Typical decrement curves for large regulated and unregulated generators are shown in Fig. 7.

RELAY CONNECTIONS

The relay should be connected to trip both the generator armature breaker *52* and the field breaker *41*, as indicated in Figs. 1 and 5. While the relay is primarily intended to provide system fault back-up protection, it also functions as back-up protection for the generator itself under certain conditions. It will operate, for example, if an internal fault in the generator windings is not cleared by the differential relays, provided sufficient current is fed into the fault from other sources. Tripping of both *41* and *52* may be effected by means of a hand-reset multicontact lockout relay *86* shown in Fig. 5. The relays *51* may also be connected to operate the lockout relay that is usually provided for the generator differential relays, although this may be undesirable if the lockout relay is also used to trip the turbine throttle.

ACCIDENTAL LOSS OF RESTRAINT POTENTIAL

Accidental loss of potential on the voltage-restrained overcurrent relay will cause the relay to trip the generator breaker if the current is 25 percent or more of the relay tap setting. Since the tap setting generally is not lower than 200 percent of full-load current, the maximum current the generator can carry without causing relay operation upon loss of restraint voltage is 50 percent of full-load current. This characteristic of the relay should not be the cause of any great concern, however, because the accidental loss of generator potential is a rare occurrence. If for any reason, the potential transformers must be de-energized while the generator is in operation, removal of the relay test plugs will prevent the relay from tripping the breaker.

Automatic protection against accidental loss of restraint potential is available for important generators where additional safeguards are necessary or economically warranted. One form of this protection consists of an instantaneous polyphase voltage-balance relay for each generator. One set of coils is energized from the generator potential transformers and the opposing set of coils is energized from the bus potential transformers.

The relay contacts remain inoperative as long as the voltages from the two sets of potential transformers are substantially equal. However, if the voltages differ, as would be the case if any potential transformer is de-energized, if any fuse is blown, or if a secondary fault develops, the relay operates to open one contact in the trip circuit of the overcurrent relays and to close another contact to sound an alarm. Suitable provision is made to prevent incorrect tripping or sounding of the alarm when the generator is being started up or shut down, and when the relays are disconnected and connected by their own test plugs.

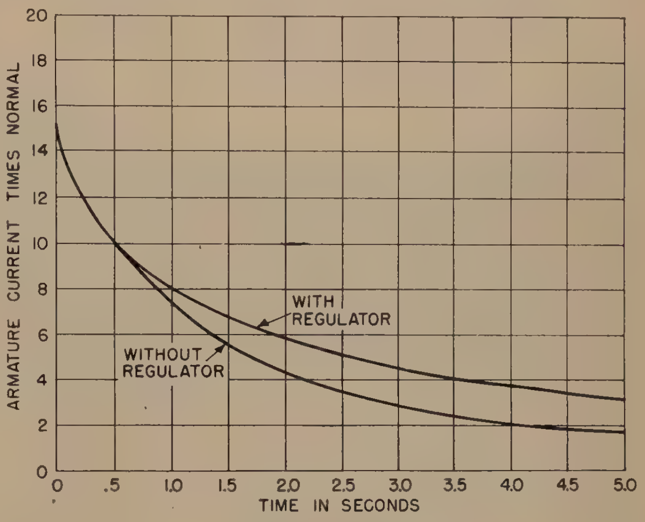


Fig. 7. Generator decrement curves

SUMMARY

System fault back-up protection should be provided at the source of fault current, the generator. A simple and satisfactory relay for the purpose is a voltage-restrained overcurrent relay adjusted to suit the characteristics of the generator and the system. The relay should generally be set to pick up with full voltage restraint between 150 percent and 200 percent full load on unregulated generators and between 200 percent and 250 percent full load on regulated generators. The time setting is determined by system selectivity requirements. Three single-phase relays are required for each generator, with potential coils energized at line-to-line potential. The relay should be connected to trip both the generator armature and field breakers for best protection. Where required, an additional relay is available for protection against accidental loss of restraint potential.

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PROTECTIVE ATMOSPHERES IN INDUSTRY . . Part XIII

Further methods for heat-treating metals—hardening, electric-furnace brazing, powder metallurgy, and gas carburizing—in which protective atmospheres are being used to good advantage. Typical applications

By A. G. HOTCHKISS and H. M. WEBBER
Industrial Heating Divisions, General Electric Company

WITH Part XII* there began a résumé covering a variety of applications of protective atmospheres, explaining where, why, and how they are utilized to advantage. This part continues with an analysis of protective atmospheres used for heat-treatment of metals.

HARDENING

Tools and Dies

Tools, dies, and small lots of gears and other machined parts are commonly heat-treated in box-type controlled-atmosphere furnaces where hand-quenching is desirable or necessary. Steels treated in this manner are high-carbon or carburized parts, containing in the order of 0.80 to 1.10 percent carbon throughout or in the surface, for which nondecarburizing atmospheres, such as Neutralene (E2a in Table I) or Thermalene (F1a), are utilized. For most steels, a single box-type furnace commonly handles such requirements; but for high-speed steels, two box-type furnaces are ordinarily used, one operating at about 1500 F for preheating, the other at about 2250 to 2350 F for the high-temperature heating preparatory to quenching. The two-furnace combination minimizes the time at high temperature, which favors the results from several standpoints, such as minimum heat-shock, grain growth, and decarburization.

Advantages of heat-treating in the box-type furnaces include uniform hardening, which is a result of uniform heating, plus the absence of scale and decarburization, and lower over-all cost, due to this uniformity and the elimination of grinding and machining operations resulting from the absence of scale and decarburization.

A typical tool-room heat-treating equipment is shown in FIG. 132. Two box-type furnaces are illustrated, the one at the left being utilized for heat-treating standard steels and preheating high-speed steels. At the right is shown the high-heat furnace, with an operator charging a preheated high-speed steel part through the opened door onto the hearthplate. A transparent gas-flame curtain is burning across the door opening, to minimize infiltration of air, thus preserving the purity of the nondecarburizing protective atmosphere. After the part is heated thoroughly, it is removed and transferred through the air to an oil-quench tank.

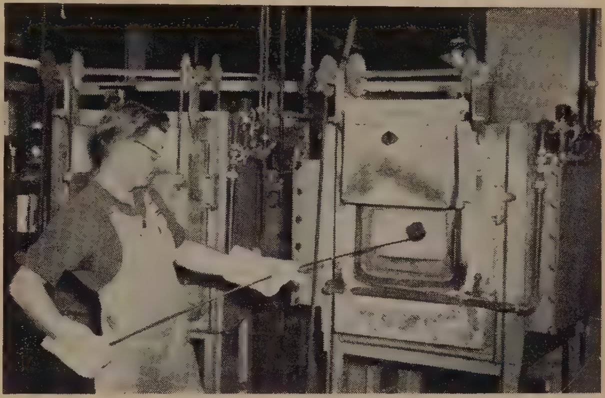

Fig. 132. Operator transferring high-speed steel part from preheating furnace (*left*) to high-heat furnace (*right*) for heat-treating in protective atmosphere, utilizing box-type furnaces

Small parts from the furnace are handled on rods, with tongs, or in trays or pans, and dumped into the quenching medium. Dies, particularly the large-size ones, are ordinarily made of air-hardening steel, requiring heat-treating temperatures of about 1850 F. These are usually handled with tongs, often with the aid of a crane, and set out in the room for air-cooling. During the air-cooling period, some scaling develops which can be eliminated, if preferred, by cooling in a protective-atmosphere chamber adjoining the heating chamber.

High-production Parts

Hardening of a large quantity of parts in production ordinarily is done in a belt-conveyor-type furnace, such as that illustrated in FIGS. 3 and 133. Items heat-treated continuously in such equipment include: stamped typewriter parts$^{(34)}$; machined drill-chuck parts such as sleeves, jaws, and keys; alloy-steel cap screws; and miscellaneous gears$^{(35)}$, pinions, splines, and other finish-machined parts, both light and heavy-weight. Materials used are medium- or high-carbon

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*The following will facilitate the location of material published in earlier parts of this serial:

Part	*Issue*	*Figs.*	*Equations*	*Tables*	*Footnotes*
Part I	Nov. 1948, p. 29	1 to 6	None	I and II	None
Part II	Dec. 1948, p. 41	7 to 14	(1) to (18)	III and IV	(1) to (9)
Part III	Feb. 1949, p. 37	15 to 23	None	V and VI	None
Part IV	Mar. 1949, p. 25	24 to 35	None	VII	None
Part V	Apr. 1949, p. 25	36 to 41	None	VIII to X	(10) and (11)
Part VI	May 1949, p. 30	42 to 54	None	XI to XII	(12)
Part VII	June 1949, p. 33	55 to 70	None	XIII to XV	(13) to (17)
Part VIII	July 1949, p. 32	71 to 89	None	XVI	(18 to (23)
Part IX	Aug. 1949, p. 26	90 to 97	None	None	None
Part X	Sept. 1949, p. 38	98 to 108	None	XVII to XIX	(24) and (25)
Part XI	Nov. 1949, p. 30	109 to 116	None	None	(26) to (29)
Part XII	Dec. 1949, p. 46	117 to 131	None	None	(30) to (33)

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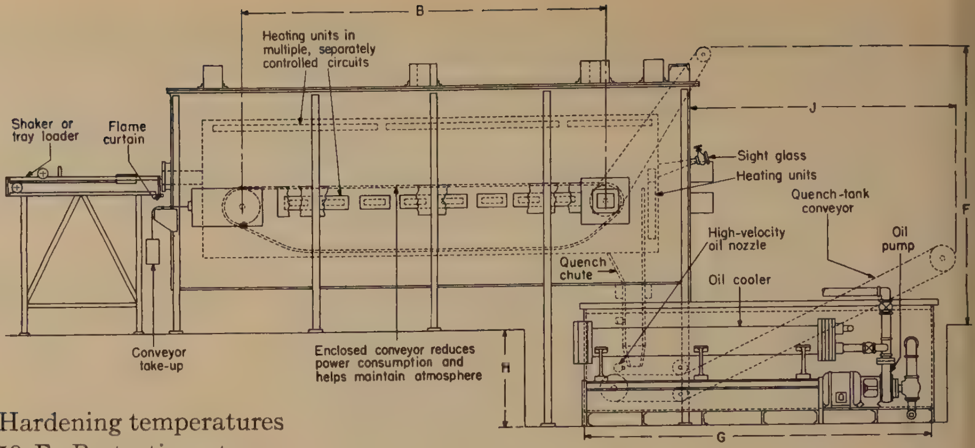
Fig. 133. Continuous belt-conveyor-type furnace for heating and quenching steel parts in protective atmosphere to avoid scaling and decarburization



steel, or carburized steel parts. Hardening temperatures are of the order of 1450 to 1550 F. Protective atmospheres utilized are commonly of the nondecarburizing type, such as Neutralene (E2a in Table I) or Thermalene (Fla).

Here again, protective atmospheres save money because they eliminate the removal of scale or decarburized skins on the surfaces of the parts. The continuous feature of the electric furnace minimizes handling expense and provides maximum uniformity of the products.

During operation of the furnace, the work parts to be heat-treated are placed on a tray loader or shaker loader, indicated at the extreme left in Fig. 133. They are then charged through the furnace door and placed on a cast-link-type conveyor, which operates over pulleys within the heating chamber and provides a constantly hot hearth. The work is carried slowly along until it is heated through; then it drops off the conveyor at the discharge end, falling through a quench chute which is located in the bottom of the furnace, and which is sealed in the quenching medium, such as oil or water, contained in an external tank. The work drops onto an immersed conveyor in the bottom of the quench tank and is carried out on an upward incline, being dumped into tote boxes at approximately floor level. From this point, the hardened parts are usually washed or degreased and then drawn in another furnace or oven.

These continuous furnaces are used for a wide variety of products over a considerable range of production rates. For example, small stamped typewriter parts, with production up to 80 lb net per hour, are treated in small conveyor-type furnaces. A variety of other work is handled in intermediate-size furnaces; and large machined parts, such as gears and splines weighing up to 35 lb each, are heated and automatically quenched as described in furnaces rated up to 1500 lb net per hour. Gears weighing up to 70 lb are similarly heated but manually quenched.

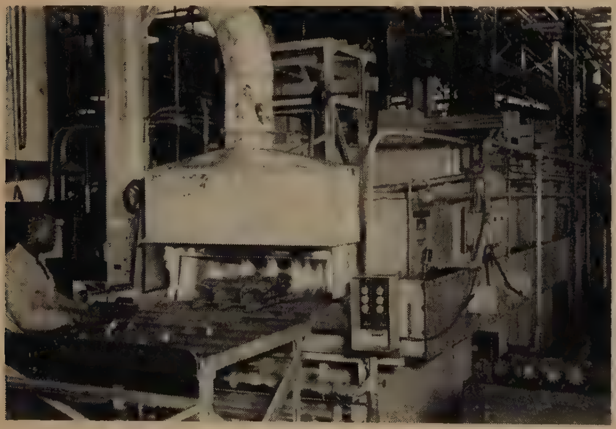


Fig. 134. Trayload of splined shafts and pinions entering charging vestibule of roller-hearth conveyor-type heat-treating furnace. The parts are individually fixture-quenched at discharge end

Another continuous-type heat-treating furnace is the roller-hearth-type equipment shown in Fig. 134. It is utilized mainly for large splined shafts and pinions (such as illustrated) and large gears, many of which require fixture-quenching and involve handling the parts one at a time at the discharge end of the furnace. The advantages again include: minimum handling; a high degree of uniformity of heating; and minimum oxidation and decarburization.

The splined shafts and pinions are carried through the furnace on trays, as shown, while many of the large gears rest directly on the roller conveyor. The furnace doors are normally closed. Work is automatically charged and discharged, and passed through gas-flame curtains at the door openings. When a tray runs out on the discharge table, the operator removes the shafts and pinions one at a time with tongs, quickly dropping them into quenching fixtures which automatically clamp and quench the parts.

Cutlery

Blades for high-quality cutlery, consisting of high-carbon stainless steel and chrome-vanadium steel, are heat-treated at 1900 F and 1650 F respectively in the electric rotary-hearth-type furnace shown in Fig. 135. Because decarburization cannot be tolerated, the parts are treated in a nondecarburizing protective atmosphere of low-ratio Neutralene (E2aI in Table I), having analysis of about 0.0 percent CO_2, 10.5 percent CO, 15.5 percent H_2, 1.5 percent CH_4, and 72.5 percent N_2, with a dew point of −40 F. The blades vary in length from 6 to 22 in. and in width up to 2 in.

Advantages of heat-treating the blades in the rotary-hearth furnace include: uniform hardness, due to the good control of temperature; freedom from scaling and decarburization, which eliminates excessive grinding and polishing; minimum labor, due to the fact that one operator charges and discharges the work by hand with the conveyorized hearth; and low over-all cost.

The pans or trays on which the blades are loaded are shown in Fig. 135. An operator is removing a trayload of work, about to quench it in the oil-quenching tank. The tray itself is not quenched. Lugs are fastened on the trays for convenient handling by tongs. The furnace has two doors: one for charging, which is hidden behind the operator in the illustration; the other for discharging, shown open. The furnace is rated 120 kw.

Magnesium-alloy Castings

In the solution heat-treatment of magnesium-alloy castings, using an air atmosphere, the castings can burn with great violence. Although the tendency to ignite is not great at the usual treating temperature of approximately 770 F, there have been instances, however, when powdered alloy or fine shavings have ignited, causing fires. It is therefore common practice to use a little sulfur dioxide in air as a protective atmosphere when the heat-treatment is such that the temperature is in the neighborhood of 800 F. The sulfur-dioxide atmosphere is obtained by piping the gas to the furnace from bottles, or by placing a metal basket of sulfur in the furnace and allowing sulfur dioxide to be formed by combustion of the sulfur and air in the furnace. Fig. 136 shows a typical elevator-type furnace for this operation, with the loading platform lowered and the loading racks in position.

Advantages of the elevator-type furnace for the solution heat-treatment of magnesium alloys include: tight seal for protective atmosphere; uniform physical properties, due to close temperature of ±5 F throughout the charge; and protection against overheating of work by alloy baffles and circulating fans.

Only a small amount of SO_2 (0.5 percent) is necessary in the air atmosphere within the furnace to give protection against the fire hazard.

A remarkable increase in strength is obtained by the solution heat-treatment, the nature of which treatment varies with the type of alloy. A typical treatment for Dow Chemical Alloy C is 20 hr at 760 F, and for Alloy H, 12 hr at 730 F, including the heating-up time. Following the solution heat-treatment, the material s removed from the furnace and air-cooled. The furnaces are usually provided with inlet and outlet connections so that the SO_2 can be purged with a blower o the outside before the loading platform is lowered.

ELECTRIC-FURNACE-BRAZING

Electric-furnace-brazing(36) is used rather generally or fabrication of ferrous and nonferrous parts. Castngs, forgings, and parts machined from bar stock are ften redesigned and fabricated from inexpensive tampings, screw-machine parts, and pieces of tubing, he object being to save material, minimize machining perations, and reduce costs. The assemblies have trong bonds, neat fillets, and bright, clean surfaces.

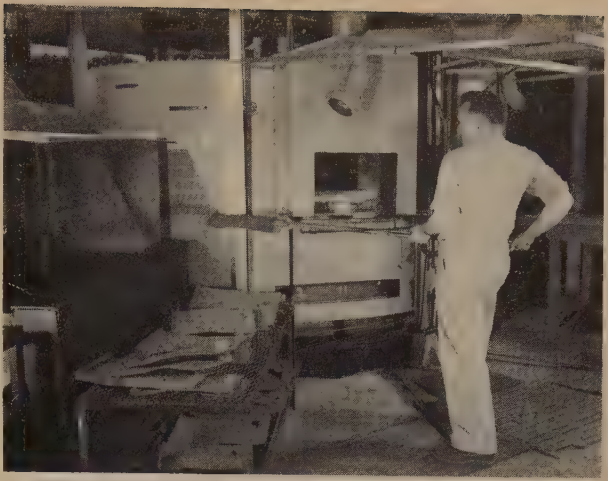


Fig. 135. Operator quenching a trayload of cutlery blades heated in rotary-hearth-type furnace in nondecarburizing Neutralene protective atmosphere

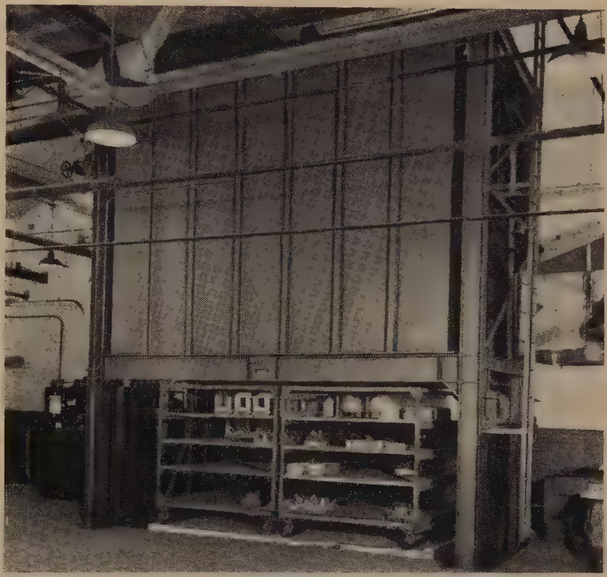


Fig. 136. To avoid fires, magnesium-alloy castings on the loading platform are heat-treated with a small amount of sulfur dioxide in the air atmosphere in the elevator-type furnace

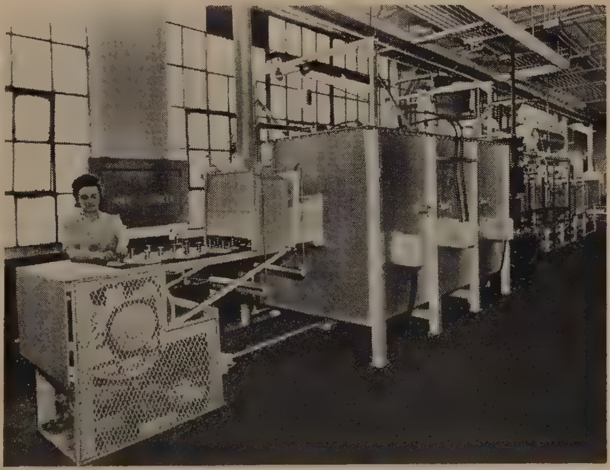


Fig. 137. The mesh-belt conveyor-type furnace is commonly employed for electric-furnace-brazing operations

In FIG. 137, an operator is shown loading subassemblies for gas-pressure regulator heads onto the belt at the charging end of a mesh-belt conveyor-type copper-brazing furnace. Other common types of brazing furnaces are the box and roller-hearth conveyor type. All have heating chambers with attached water-jacketed cooling chambers. They are used for fabricating parts for automobiles, rockets, airplanes and ships, bicycles, business machines, refrigerators and stoves, etc.

Low-carbon Steel

A typical assembly—formerly cast, now furnace-brazed—is the burner for camp and trailer stoves shown in FIG. 138. This application of furnace-brazing has paid attractive dividends. Now made with five stampings and three screw-machine parts, assembled with copper wires preplaced at the joints to serve as brazing metal, the fabricated burner has reduced the weight 3½ lb, saving money in both freight and material costs. In addition, the portable stove is now easier to carry. No special setups and machining operations are required other than the inexpensive operations performed on screw-machines, which result in further savings. Inside dimensions of the burner are more uniform, thus permitting free flow of gas for better operation. Moreover, less inventory is involved with the fabricated burner. The flexible construction, utilizing threaded tube connectors of various lengths for two- or three-burner stoves, makes it necessary to stock only one supply of burners with a variety of tube connectors, instead of various supplies of cast multiple type burners.

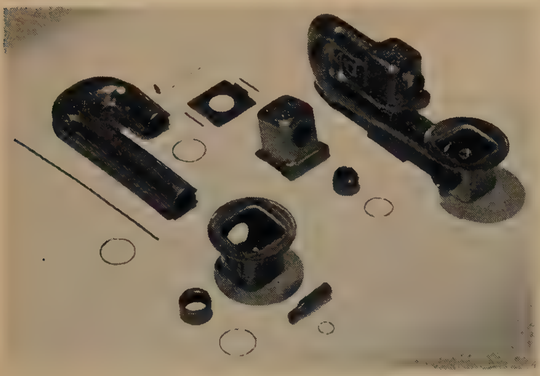


Fig. 138. Product of brazing furnace: a burner for camp and trailer stove (*right*), formerly cast, now made with five stampings and three screw-machine parts (*left*)

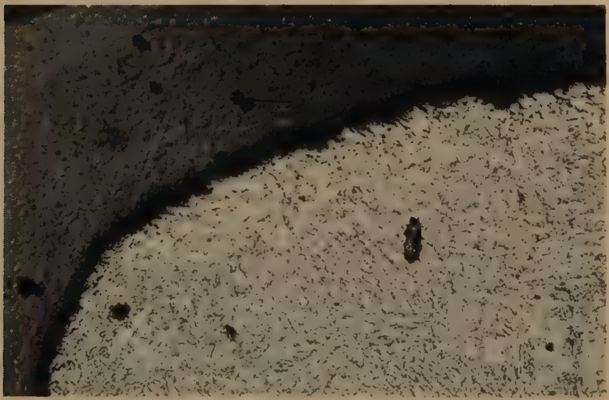


Fig. 139. Photomicrograph (×250) of SAE-4130 steel, copper-brazed in Neutralene gas atmosphere in a box-type furnace at a temperature of 2080 F. Note absence of decarburization

The Venturi-and-burner unit shown at the extrem right in FIG. 138 consists of a U-shaped Venturi made of two stampings having the crimped seams at the edges, a rectangular stamped box pressed and staked over each end, and fittings staked into the sides of the boxes. A straight piece of copper wire inside the Venturi, at the bottom, and copper-wire rings around the other joints, melt in the controlled-atmosphere furnace and creep throughout all of the seams to give strong, tight bonds. No subsequent cleaning operations are necessary because the assemblies come from the mesh-belt furnace clean and bright. The protective atmosphere is combusted fuel gas (E1a in Table I) made by partial combustion of natural gas with air.

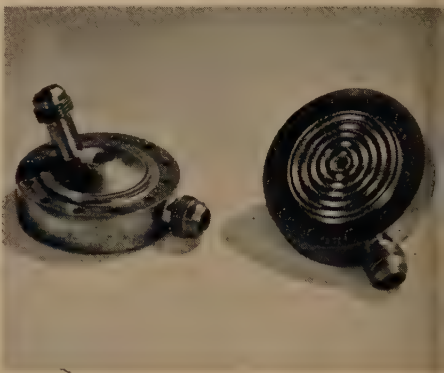


Fig. 140. Bright-brazed 18-8 stainless-steel assembly treated in metal retort. Protective atmosphere is pure dry hydrogen or dissociated ammonia

Medium- or High-carbon Steel

When furnace-brazing medium- or high-carbon steel it is desired not only to get good wetting of the parent metal by the brazing metal, such as can be obtained with combusted fuel gas, but also to prevent surface decarburization of the parent metal. Protective atmospheres commonly utilized for furnace-brazing without decarburization are Neutralene (E2a in Table I) and Thermalene (F1a). Assemblies which are furnace-brazed and subsequently heat-treated in such atmospheres have the desired surface hardness without need of grinding or machining operations which would otherwise be required to remove a soft decarburized skin.

FIG. 139 is a typical photomicrograph of an SAE-4130 steel part, copper-brazed at 2080 F in Neutralene gas atmosphere in a box-type furnace. The analysis of the protective gas entering the furnace was 0.0 percent CO_2, 11.7 percent CO, 19.2 percent H_2, 0.8 percent CH_4, 68.3 percent N_2, with a dew point of −50 F. A gas sample taken from the furnace had a dew point of +5 F. Note that there is no indication of decarburization at the surface.

Stainless Steel

The bright-brazing of stainless steel and other high chromium alloys with copper in highly purified protective atmospheres is now considered a successful production method.(37) The 18Cr-8Ni stainless-steel assembly shown in two views in FIG. 140 is a typical example

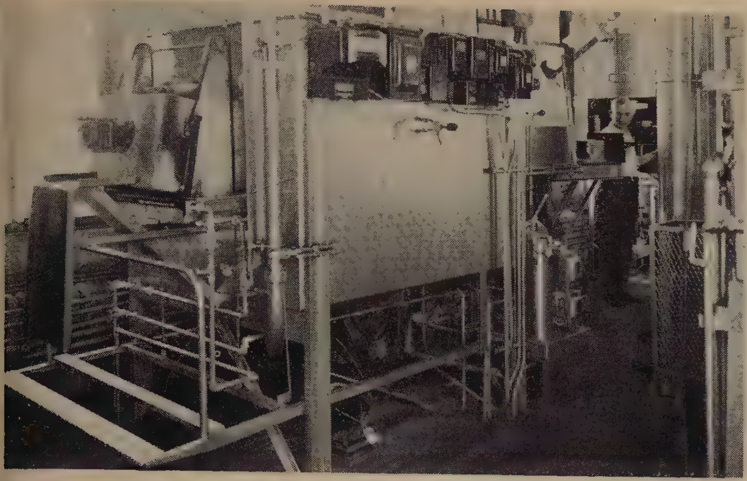


Fig. 141. Operator at right is shown pushing a charge of high-chromium alloy parts into charging-and-cooling vestibule of box-type furnace. Heating chamber is in center

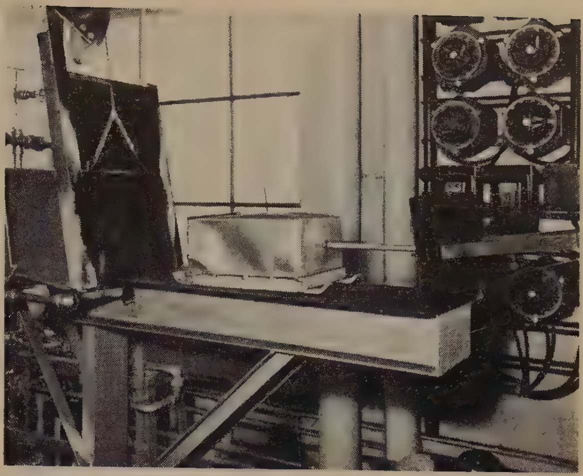


Fig. 142. Sheet-metal retort (*center*) with gas-inlet tube and door plug ready to be inserted in charging vestibule and cooling chamber of box-type furnace for bright-brazing high-chromium alloy parts

Although this gives a good idea of the outside appearance of the brazed assembly, it does not show the interior, which is honeycombed with machined ducts and radial holes. The ducts are covered with annular rings in which tiny holes are drilled prior to assembling. These rings must be bonded tightly and strongly to the body of the assembly, keeping the interiors of the ducts completely free from any particles of oxides or flux which, if loosened, might clog the tiny holes. With so many joints to be brazed in one assembly, and with this requirement for cleanliness, bright furnace-brazing obviously is the right way to do the job. Accordingly, the product was developed to be made by this method, and the results have been successful.

The assembly is brazed in two trips through a furnace such as the box-type shown in Fig. 141, or in a bell-type furnace. The work is enclosed in a sheet-metal retort, Fig. 142, with a gas-inlet tube supplying pure dry hydrogen or dissociated ammonia into the retort throughout the heating and cooling cycles. First, two fittings, Fig. 140 (*left*), and one annular ring are brazed into the top side, with copper-wire rings at the joints. Then the assembly is turned over, Fig. 140 (*right*), and the five annular rings on the back side are similarly brazed over the ducts.

Nonferrous Assembly

Typical of a variety of nonferrous assemblies furnace-brazed with low-melting brazing metals, such as silver-brazing alloys, is the stuffing-box assembly, Fig. 143. It was formerly cast and machined but, because of porosity, rejections were excessively high. Now that it is made of two parts machined from brass bar stock, shown in Fig. 143 at the left, with the silver-brazing-alloy ring preplaced at the joint, this difficulty has been completely overcome, and the over-all cost is lower.

In this instance, the parts are fluxed at the time of the assembling operation, to assure wetting of the brass by the silver-brazing alloy. After furnace-brazing, cleaning and bright-dipping operations are utilized to remove flux and zinc-oxide deposits from the surfaces of the parts. The furnace-brazed assembly shown at the right in Fig. 143 illustrates the final appearance after these operations, and after a final machining and threading operation on the flange. While passing through the furnace, the assemblies are in the inverted position from that shown, to permit use of round rings instead of hexagonal ones, and to properly direct the flow of the brazing metal by the aid of gravity.

Other nonferrous metals used for assemblies which are furnace-brazed include: bronze, copper, copper-nickel alloys, nickel, sterling silver, nickel silver, a few aluminum alloys, a magnesium alloy, etc.

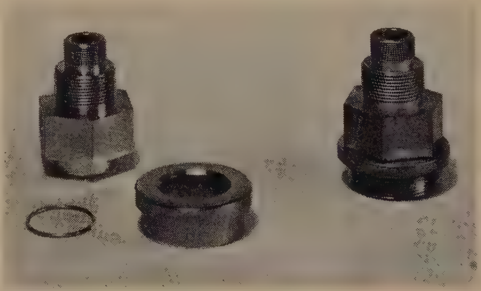


Fig. 143. Brass stuffing box as furnace-brazed (*right*) is made from two parts machined from bar stock (*left*). Porosity of former casting was overcome at reduced cost

POWDER METALLURGY

A growing field in which protective atmospheres play an important role is that of powder metallurgy[38], [39]. The whole art of powder metallurgy revolves, in fact, around the use of protective atmospheres in furnaces. Operations in which the atmospheres are involved to the greatest extent are: annealing of powders during their manufacture, and sintering of pressed powder compacts. A wide variety of parts is made by powder metallurgy, for a diversified market, typical of which are porous oil-impregnated bearings, machine parts, gears, cams, radio cores, clutch facings, etc. The powders are compacted in dies under high pressure into the shape of the parts. The compacts are then

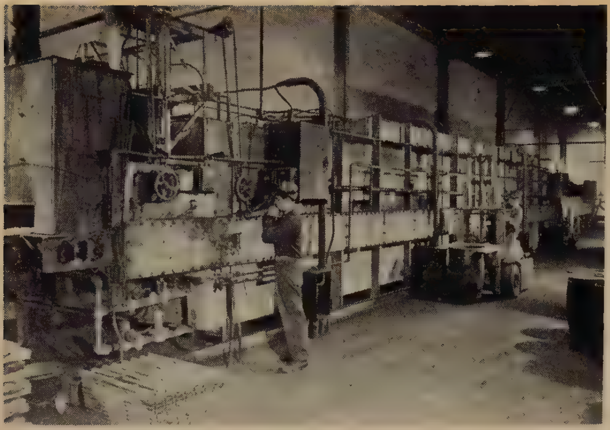


Fig. 144. Metal powders used in the art of powder metallurgy are sometimes made electrolytically. Ball-milling in processing hardens powder particles and requires subsequent annealing in protective-atmosphere furnaces, such as the roller-hearth conveyor-type shown here

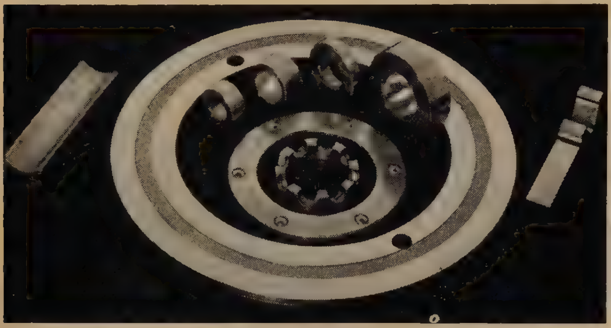


Fig. 145. Pressed-bronze powder compacts are sintered in protective-atmosphere furnaces to make a variety of parts such as bearings and ball race shown above. Porosity of parts is often a valuable property for retaining oil

sintered at high temperature in protective atmosphere until surface diffusion takes place at the interfaces of the particles. Emphasis is frequently put on the possibility of making cost savings by pressing and sintering parts to eliminate machining operations.

Making Metal Powders

Metal powders are made by at least eleven different processes.(40) One method which uses protective atmospheres, and which results in powders of high purity, is the electrolytic process. For many sintered products, the purity of the powders is important. Copper and iron powders, as well as powders of other metals, are made this way.

In making powders electrolytically, plates of copper or iron are lowered into the tanks and connected as anodes. Direct current flows from these plates through the electrolyte to cathodes, carrying copper or iron with it. The metal is deposited as a high-purity brittle plate, with the impurities in the original anodes settling out. The cathodes are removed at certain intervals, and the cathode deposit is knocked off. This brittle deposit is broken up in a hammer mill and ground to a fine powder in a conical ball mill.

Then, to soften the particles, the powder is annealed in a furnace, such as the large roller-hearth conveyor-type furnace in Fig. 144. A hydrogen or hydrogen-bearing atmosphere is used throughout the heating and cooling chambers to prevent oxidation of the powder, and to reduce any oxides which may be present. Panloads of the powder are carried continuously through the furnace; when they emerge, the cakes of powder are broken up again. After this repowdering operation, the powder is carefully blended to the customer's specifications, and the finished powders are sealed in steel drums for shipment.

Sintering

Sintering is a fundamental process in powder metallurgy whereby solid bodies are bonded by atomic forces. The action is accelerated by heating pressed powder compacts in controlled-atmosphere furnaces, often below the melting point of any of the constituents, causing recrystallization and grain growth by surface diffusion of the atoms. After heating, the work is cooled in a protective atmosphere to 300 F, or lower, so that it will remain bright when it contacts the air.

Although there is a wide variety of powders and combinations of powders used in sintered parts (the selection of which influences the mechanical and physical properties) the common ones encountered are: copper-tin-graphite mixtures, sintered at 1400 to 1600 F, used largely for self-lubricating bearings; brass parts, such as gears, lock parts, filters, etc., sintered at 1500 to 1700 F; and iron-powder parts, sintered at 2000 to 2050 F, used largely as self-lubricated bearings, gears, cams, etc.

Bronze Parts

Some typical bronze parts made by powder metallurgy are shown in Fig. 145. At the left is a half-bearing, at the extreme right is a cam bearing, in the center is a ball race encircled by two thrust plates, and within the outer ring are four sleeve bearings. Most of these parts are given a final sizing or coining operation after sintering to assure accurate dimensions. Most of these sintered parts are porous; for bearings this is a desirable condition because they can hold from 20 to 30 percent of their volume in oil to obtain a self-lubricat-

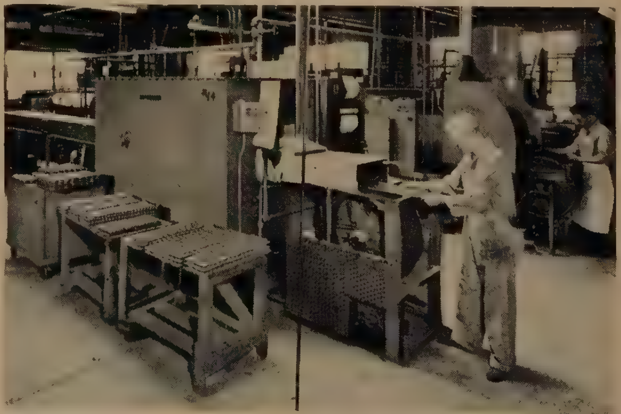


Fig. 146. Two mesh-belt conveyor-type furnaces, sintering trayloads of "green" compacts. Bronze, brass, and iron parts are typical of those treated in protective atmospheres

ing property, and they do not require high strength. The bearings, therefore, are dipped in oil after coining. In addition to the porous parts, more dense and stronger ones are also sometimes made.

Iron Parts

Typical parts made from pressed compacts of iron powder, which sometimes contain graphite, are shown on the COVER. Included in the illustration is a thrust bearing, several sleeve bearings, and gears for washing-machines and automobile oil pumps. Some iron gears contain copper for increased strength, obtained either by mixing copper powder with the iron powder, or by allowing sintered iron parts to absorb molten copper in a second heating operation. Sintered gears are usually of higher quality than cast ones, because the teeth are more accurately shaped and have better surface finish, which results in superior pumping efficiency and quietness of operation.

In a typical example, the cost is lower than the cut gears because, after the gears are cast, 64 percent of the material is machined away, whereas there is practically no waste of material for the sintered ones. Also, because there is 20 percent porosity by volume in the sintered gears, the weight is correspondingly less than that of the cast ones, and therefore less material is needed in the final product. This is a typical part which is accurately made at reduced cost, even though the powdered metal is somewhat more expensive than the cast metal.

Sintering Furnaces and Atmospheres

Sintering furnaces are built in a variety of types(41); the most common ones are the box, mesh-belt conveyor, and roller-hearth conveyor types. For all of these furnaces, the equipment consists of a heating chamber with attached cooling chamber, an example of which is the mesh-belt sintering furnace, FIG. 146.

In some instances, preheating chambers have been added to distill out the lubricants from "green" compacts being sintered, so that the carbonaceous vapor will be exhausted at the entering end. Protective atmospheres for sintering bronze parts(42) are usually low-ratio combusted gas (E1a in Table I). A typical analysis when burning at 8:1 air-gas ratio using natural gas (FIG. 28 in Part IV) is about 8 percent CO_2, 6 percent CO, 7 percent H_2, 0.0 percent CH_4, and 79 percent N_2. Lower ratios with higher reducing constituents can be used, but the 8:1 ratio gives a gas which is adequate for bronze parts, is slightly less inflammable, and has slightly lower cost, which accounts for its frequent choice.

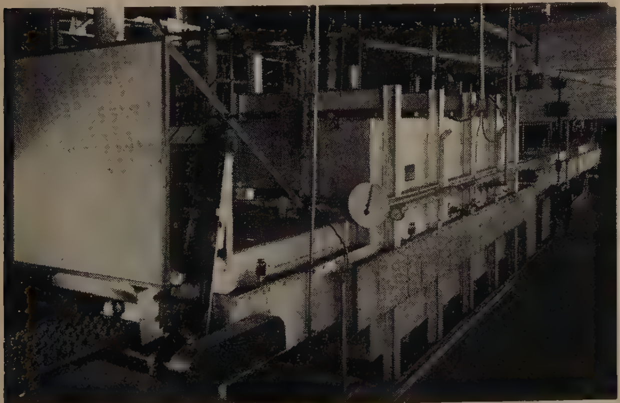


Fig. 147. Trayload (*left*) of iron compacts entering charging vestibule of roller-hearth conveyor-type sintering furnace, with Neutralene protective atmosphere which prevents decarburization

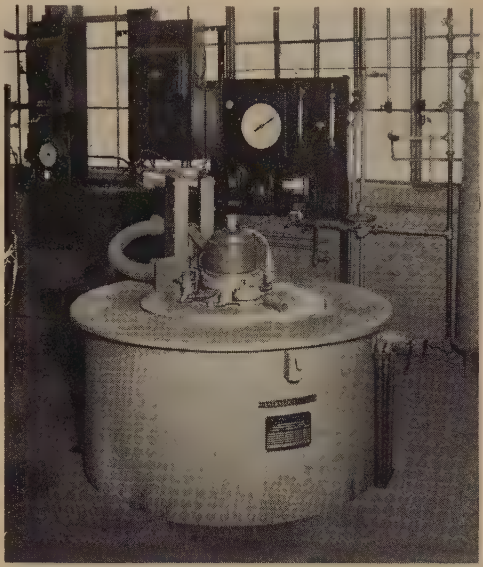


Fig. 148. Pit-type gas-carburizing furnace with circulating fan in cover for carburizing gears, shafts, and pins in natural-gas atmosphere. The work is enclosed in a metal retort

A trayload of iron sleeve bearings is shown entering a roller-hearth sintering furnace in FIG. 147. The furnace operates at about 2050 F. The protective atmosphere is Neutralene (E2aI in Table I), consisting of 0.0 percent CO_2, 10.5 percent CO, 15.5 percent H_2, 1.5 percent CH_4, and 75.5 percent N_2, with a dew point of −40F. This atmosphere effectively sinters parts without surface decarburization, as explained in Part VI, with FIGS. 47, 48, and 49 as illustrations.

GAS CARBURIZING

The carburizing process is used widely on machined-steel parts requiring hardened surfaces for maximum wearing properties. Shafts, splines, gears, etc. are easily machined from low-carbon steel which, after carburizing, can be hardened by heat-treatment.

Gas carburizing(13) has generally replaced the older pack method (Part VII), especially in such manufacturing plants as tractor, automotive, and aviation industries. The gas method offers advantages, such as less handling of parts, shorter treating cycle, cleaner surface, more uniform case, and full control of carbon concentration and case depth.

FIG. 148 shows a typical batch-type gas carburizing furnace, similar to that described in Part VII and illustrated in FIGS. 57 and 58. This furnace is used for carburizing gears, shafts, and pins of many different sizes. A typical load consisted of 1768 lb of fairly small pieces measuring from ⅝ in. to 1½ in. across, loaded at random. The temperature cycle for this load, shown in Fig. 149, indicates that the furnace temperature (outside of the retort) reaches 1700 F in about 1½ hr after charging; the load comes to the same point in about 3 hr, and the load is held at temperature 6 hr. At the end of the holding cycle, the removable basket containing the load is transferred to an insulated chamber, where it is cooled for about 8 hr in a protective atmosphere.

The progress of the carburizing action is indicated by the lower curve, which gives the case depth for each hour at temperature. Test bars were suspended through a sampling hole in the top of the furnace and withdrawn each hour, quenched, broken, and the case depth measured. Other samples buried in this particular load at four different levels from top to bottom, when measured at the end of the run, indicated a uniformity of case depth within a range of ±0.004 in. The carburizing atmosphere was straight natural gas introduced at the rate of 32 cfh throughout the run. The average dew point of the gas surrounding the work in the furnace was +14 F.

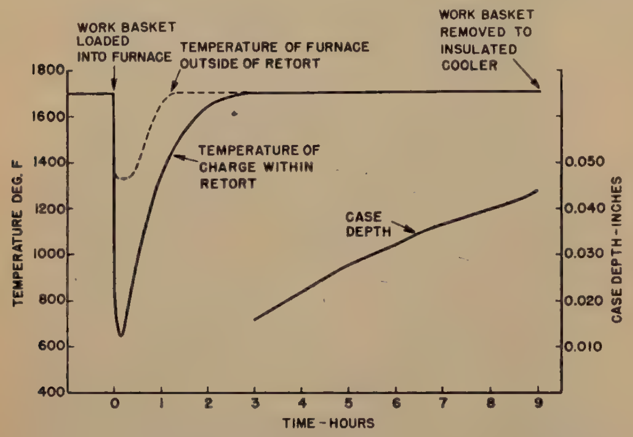


Fig. 149. Typical temperature-time cycle in pit-type gas-carburizing furnace showing temperature changes in the furnace and the load (*upper curves*), and case depth in parts as time progresses (*lower curve*)

By use of a carrier gas(14), such as Neutralene or Thermalene (E1a and F1a, Table I), the amount of natural gas can be greatly reduced, resulting in less free soot or carbon deposit and permitting a more definite control of the carburizing process. For instance, if it is found desirable to diffuse the high-carbon case into the core, the natural gas can be decreased or stopped for the required time to obtain the diffusion.

CARBON RESTORATION

Some decarburization takes place in the mill processing of many carbon steels. When these materials are used in the manufacture of finished parts which are subsequently heat-treated, the low-carbon surface will not be hard. This condition can be corrected either by removing the low-carbon surface skin, or by restoring the carbon to the surface at the mill or in the finished parts. To save both material and time, carbon restoration in the raw or finished material is being increasingly used. This subject is explained at length in Part VII. It is customary to perform the carbon-restoration treatment during a usual annealing or hardening operation, and at such times the desired surface condition is obtained without an additional operation and at minimum over-all cost.

Mill Stock

Mill stock is in coils or straight-rod form. In either instance, a rectangular bell-type furnace can be used, and the process carried out during an annealing cycle. The work is enclosed in a sheet-metal cover. A single load-supporting base can carry several stacks of coils, each with its separate cover, or a load of straight bars supported on racks under a single rectangular cover. The bell-type furnace is placed over the load for heating and removed at the end of the heating cycle to allow the work to cool somewhat before removing the covers.

The covers are purged with a protective atmosphere, either purified N_2 (B2 in Table I) or Neutralene (nearly completely burned, E2b). As the work begins to come up to temperature, a small amount of enriching hydrocarbon gas (natural gas or propane) is introduced. The amount of enrichment gas needed can be determined by measuring the dew point in the retort covers and by past experience. Such an annealing and carbon-restoration cycle for a 12,000 lb load may require 8 to 10 hr for heating, 4 to 6 hr holding, and about 14 hr cooling.

The stock to be treated for carbon restoration must be pickled and should be free of mill scale for best results, since this scale will reduce, forming water vapor and producing decarburizing conditions.

Finished Parts

In the manufacturing of such items as bolts and screw-machine parts, the carbon restoration can be accomplished in the hardening operation. Actually, the soft decarburized skin on the bar stock facilitates the rolling of threads on bolts and minimizes wear on the forming machine.

After the threads are rolled on the bolts, the hardening process is carried out in a conveyor-type furnace, Figs. 3 and 133, arranged to heat the parts and drop them into either an oil- or water-quench at the end of the cycle. In a typical installation, the protective atmosphere is Thermalene (F1a) introduced with a dew point of about +10 to 15 F. The dew point maintained in the furnace is about +40 F to produce a carbon potential suitable to restore the surface of the work to 0.40 percent carbon. When the decarburized surface is 0.004 to 0.008 in. deep, a time cycle of about 1½ hr total with a furnace temperature of 1550 F is sufficient for complete restoration. Control of the carbon potential is dependent on the amount of CH_4 present in the gas and the dew point maintained. The time cycle is adjusted to allow sufficient time for full penetration to the total depth of decarburization. Because of the difference in furnaces, and from the standpoint of flexibility, it is desirable to have an atmosphere generator for each furnace. Although Thermalene is used in the foregoing illustration, Neutralene gas is equally suitable.

ACKNOWLEDGMENT

Acknowledgment is made to A. R. Ryan for his assistance in the preparation of this part and the preceding part of this serial.

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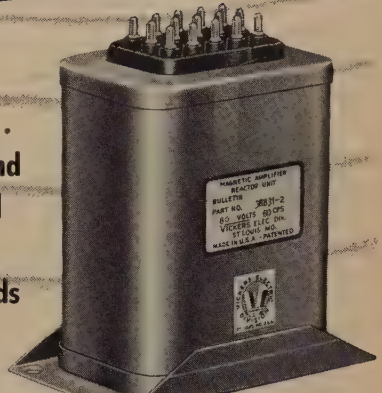

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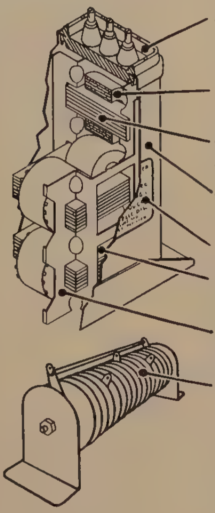

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HIGH LIGHTS AND SIDE LIGHTS

New Mercury Power Plant

The Schiller Station, said to be the most efficient electric power plant of its size in the world, was opened last month by Public Service Company of New Hampshire.

Exterior view of the Schiller Station, equipped with generating apparatus which makes combined use of mercury vapor and steam turbine units

Deriving power from the combined use of mercury-vapor and steam turbine generators, the new 40,000-kw station will be able to produce more kilowatt-hours with a given amount of fuel than any generating equipment of comparable size yet built.

Power from the station will be fed into the company's network of transmission lines which extend throughout the state. Thus, the output from Schiller Station will combine with the output from the company's six other fuel-burning plants and 31 hydroelectric plants to supply the utility's 117,000 customers in about 70 percent of New Hampshire, together with other New Hampshire electric companies and co-operatives which are normally supplied with power by Public Service. Interconnected through transmission lines with other producing companies in the New England area, Schiller Station will make a considerable addition to the total electric-generating capacity of that area.

Avery R. Schiller, president of Public Service, in whose honor the station was named, said: "We have adopted this entirely new type of system, which combines the advantages of conventional steam-generating equipment with a mercury-unit power plant, so as to try to counteract the high fuel costs by burning less fuel per unit of electricity produced."

The station includes two 7500-kw mercury-turbine generators, two mercury-boiler furnaces, two heat-exchange units called condenser-boilers, and a 25,000-kw steam-turbine generator.

Either pulverized coal or Bunker "C" oil can be used as the fuel for the mercury-boiler furnaces. In operation, liquid mercury in those furnaces is vaporized and the vapor is used to drive the two mercury turbines. After the mercury vapor has passed through those turbines, it is piped into the condenser-boilers where it gives off its latent heat to turn water into steam. This steam drives the 25,000-kw turbine generator.

The power generating equipment is housed in a welded steel frame building covered with brick and prefabricated siding.

McEachron Awarded Edison Medal

At the 1949–1950 winter meeting of the American Institute of Electrical Engineers, held in New York City, Dr. Karl B. McEachron, General Electric engineer and internationally recognized authority on lightning, was awarded the 1949 Edison Medal. This honor was conferred on him for "his contributions to the advancement of electrical science in the field of lightning and other high-voltage phenomena and for the application of this knowledge to the design and protection of electric apparatus and systems."

Among those contributions were: work in the development of the cathode-ray oscillograph to measure impulse voltages, direction of the study and measurement of lightning strokes at the Empire State Building in New York City, and direction of the development of the 10,000,000-volt artificial lightning generator used at the New York World's Fair.

Included among his other technical achievements is the invention of Thyrite nonlinear resistance material, which is used in a variety of lightning protection and other electric applications. For this work he received G.E.'s Charles A. Coffin award in 1931 and in 1935 was presented the Edward Longstreth Medal from the Franklin Institute, Philadelphia.

During the war, the medalist was chairman of the Advisory Committee on Lightning Protection, Safety and Security Division, Office of the Chief of Ordnance. He also has served with the U.S. Research and Development Board, and as section chairman and member of the board of directors of the A.I.E.E. Last September he was named manager of engineering for General Electric's Transformer and Allied Product Divisions at Pittsfield (Mass.).

Dr. McEachron is co-author with Kenneth G. Patrick of the book *Playing with Lightning*, and more recently the author of "Lightning and Lightning Protection" for the *Encyclopedia Britannica*.

The Edison award, established in 1904, was founded by an organization of friends of Thomas A. Edison who wished to commemorate the achievements of a quarter of a century in the field of electric lighting with which Edison is so prominently identified, to serve as an honorable incentive to scientists, engineers, and artisans to maintain by their works the high standards of accomplishments set by Edison.

X-ray Microscope

The internal details of materials through which light cannot pass are now made visible by an x-ray microscope.

Future refinements of the new instrument, which is at present in the laboratory stage of development, may result in much sharper images and higher magnifications than are possible with the use of visible light or electron beams.

X rays from the aperture in the cylinder (right) pass through the sample being examined and are magnified by two mirrors contained in the unit. The magnified x-ray image is cast on a photographic film mounted behind the optical system

The x-ray microscope does not require that samples under study be in a high vacuum, as does the electron microscope, the most powerful magnifying instrument in use at the present time. Because of this advantage, laboratory scientists believe it may be possible to examine living materials at much higher magnifications than ever before.

Clear, sharp x-ray images, magnified ten times, have been produced in the laboratory, and these images have been magnified ten times further by photographic enlargement without serious loss of detail. Thus, at the present stage of development, magnifications of 100 diameters have been produced by means of x rays.

Studies have been made of fine-mesh screens, to test the instrument's ability to reveal small details. Results are reported as excellent.

The microscope operates on the principle that x rays can be reflected from polished surfaces, as can visible light, provided that the rays strike the surfaces at very small angles, almost parallel to the surfaces. It consists of an x-ray tube and a pair of curved mirrors, which the x rays strike at an angle of less than one-half degree, after having passed through the sample. The mirrors bend the beams in such a way as to cast a magnified x-ray image of the sample on a photographic film.

The mirrors are platinum-coated slabs of fused quartz, which are as nearly flat as surfaces can be made. They are curved by mechanical pressure, which can be adjusted by hand to improve focusing.

The optical system, sample holder, and dials for making focusing adjustments are mounted in a compact metal unit half as large as a shoebox. The unit is placed a few inches away from the x-ray tube, with the x-ray beam passing through the sample in its holder, thence to the mirrors, and finally to a photographic film located a foot or more away from the unit.

The unit and photographic film are mounted on a long track running parallel to the x-ray beam. By this arrangement the optical system and the photographic film are moved relative to each other and to the x-ray source.

Superfine Filaments

Delicate fibers of quartz, only 1/50 of the thickness of a human hair, are being produced for use in sensitive balances and various electric measuring instruments.

Some of the fibers produced are so fine that more than ten miles of them could be wound on an ordinary-size spool that holds only 250 yards of common cotton thread.

Almost invisible to the naked eye and looking like the threads of a superfine spider web, the fibers are drawn from slender rods of quartz heated to very high temperature. The delicate threads are drawn from the molten ends of the rods and are attached to a revolving wheel, which winds a continuous fiber.

Quartz fibers produced in the laboratory are employed in making sensitive balances for use in microchemistry, in which minute weight differences must be measured. These microbalances are sensitive enough to show weight differences less than 1/30,000,000 of an ounce, yet strong enough to hold weights a million times greater. The fibers are an ideal material for use in measuring instruments, because they are not affected by temperature changes and do not lose elasticity when under continuous strain.

Fusing together quartz fibers with a tiny jet burning a special mixture of gases to make the bridge, the part of the balance from which small scalepans are suspended

Adjusting a sensitive balance, used in ultramicrochemistry to measure minute weight differences, made of delicate filaments of quartz, some 1/50 of the thickness of a human hair

A fiber of molten quartz is drawn from a slender rod being heated to 1800 C. The wheel at right revolves at various speeds to draw quartz fibers of different degrees of fineness

Fashioning the minute parts of balances and electrometers requires skill comparable to that of a watchmaker. One tiny part, in which a fingernail-size mirror is suspended by a delicate fibril of quartz between two supports, is made entirely of a single piece of quartz. Operators must wear dark glasses when fusing and drawing the fibers, because quartz gives off ultraviolet rays at high temperatures. Much of the work is done under a microscope.

Measuring Molecules With Microwaves

Tiny microwaves, similar to those used by radar sets aboard high-altitude bombers during World War II to aim bombs through thick clouds, are now being employed to measure molecules.

With such waves—a fraction of an inch long—aimed through gases, scientists are finding the dimensions of certain molecules and the rate at which they spin. One, for example, has the shape of a triangular pyramid of four atoms with a fifth atom supported above like a statue on a pedestal. It has been suggested that this molecule may spin 26,695,200,000 times per second.

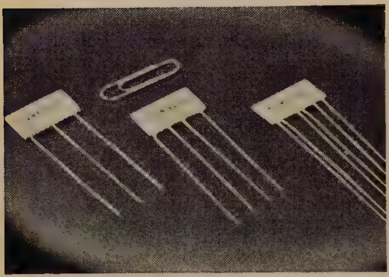
This particular molecule is known as chlorosilane, and is of fundamental importance in the chemistry of the silicones, which are rapidly finding great industrial importance as oils, greases, rubbers, metal finishes, waterproofing materials, etc.

As used by research engineers, the radio microwaves vibrate on the average about 24 million times per second. As in F-M radio broadcasts, however, this frequency swings up and down, above and below the average value, while the waves are sent through a 16-ft rectangular pipe containing the gas under study. Most of the time they pass through freely, but when they happen to be at one of the characteristic rates of the molecules, they are absorbed, and their energy sets the molecules into increased rotation.

This represents an important extension of the science of spectroscopy, used to study laboratory samples or the properties of distant stars. With visible light waves (about 50,000 to the inch) individual atoms can be studied. Invisible infrared waves, similar to those of visible light but considerably longer, can be used in measuring molecules made of groups of atoms. The still longer radio microwaves yield data several thousand times as precise as those obtained with infrared. In general, waves used in microwave spectroscopy are from about a quarter inch to five inches long.

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

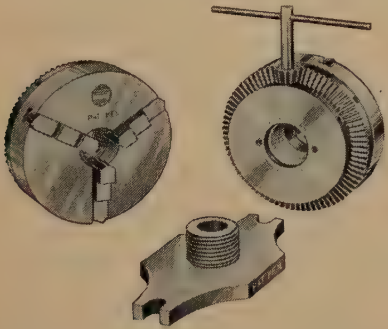
Capacitors



Wafer-thin multisection high-K ceramic Bulplate capacitors as space and cost savers for bypass and coupling applications in a wide variety of applications. The new units are furnished with either multiple sections alone or in combination with printed wiring, shielding, and other printed details. Thus, a single unit may combine all of the capacitors in one or more radio circuit stages into a compact assembly. The units are covered with a tough moisture-proof coating that protects them against short-circuiting to other components and assures satisfactory performance under severe conditions of humidity, temperature, and vibration.—*Sprague Electric Co., North Adams, Mass.*

Chuck

A new and versatile 3-jaw universal chuck, known as 75, combines the speed of a lever-operated chuck with the powerful grip of a pinion-operated chuck. The need for the usual adapter plate has been eliminated because the chuck is threaded for direct attachment to 1½-in. 8-thread lathe spindles. This chuck can also be used on a milling machine dividing head. The net weight of the chuck is 8½ lb; the reversible jaws are of heat-treated steel with precision-ground bites and steps; the body, 5 in. in diameter, is of finished semisteel; and the scroll is of durable alloy with sturdy spiral thread and teeth designed to withstand a high degree of wear and strain.—*Westcott Chuck Co., Oneida, N. Y.*

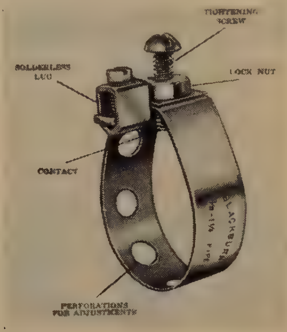


Electrical Tape

A new electrical tape known as Plastix. Superthin in construction and high in dielectric resistance, the tape has as high as 200 percent stretch and, as a result, conforms to irregular surfaces. It resists water, oil, acids, alkalies, and corrosive chemicals, and stands up under severe conditions. The tape is packaged in a convenient screw-cap container which holds five rolls.—*Van Cleef Bros., Inc., Chicago 19, Ill.*

Ground Clamp

A new adjustable ground clamp now available in two sizes: one fits ⅜-in. to 1¼-in. pipe; the other ⅜-in. to 3-in. pipe. A tightening screw chafes the pipe, draws up slack, cuts through rust and dirt, and contracts the band around the pipe surface. The clamp consists of a flexible perforated pure-copper band which encircles the pipe. A boss raised on the flat end of a removable copper-alloy terminal lug fits into band holes and is machined to give a clean, smooth contact surface. The tightening screw with a lock nut is threaded through the boss. For ease in installation, the band is properly tempered and formed at one end.—*Blackburn Specialty Co., 6541 Euclid Ave., Cleveland 3, Ohio.*



Temperature Indicators

A new line of temperature indicators for industrial and laboratory use. Cold-end compensated thermocouple thermometers for measuring temperatures up to 3000 F in galvanizing vats, melting pots, industrial furnaces, infrared drying ovens, etc., are available in Type DO-71 with a 3½-in. flange and Type DW-71 with a 2½-in. flange, both being supplied in either square or round molded Textolite cases.

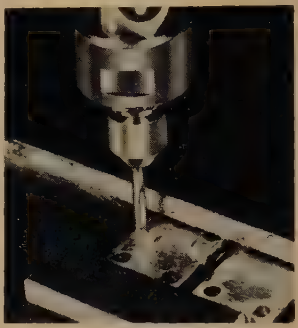
Designed for measurement of low temperatures where high accuracy is important, resistance thermometers—Type DB-15 long-scale instruments and Types DD-6 and DD-7 six-inch rectangular, surface- and flush-mounted instruments—are available. They are suitable for bearing temperature measurement, generator- and transformer-winding temperature indication, refrigeration and air-conditioning testing, drying operations, remote fluid temperature indication, etc.—*General Electric Co., Meter and Instrument Divisions, West Lynn, Mass.*

Alloy

Cerrocast, a new alloy of reasonable hardness, negligible shrinkage, and an extensive melting range of 281 F to 338 F. It is a non-eutectic alloy of bismuth and tin and is especially suitable for use in precision casting. Because of its long melting range, this alloy can be coined readily to accurately reproduce the shape, dimensions, and fine surface details of a master pattern. This product also works satisfactorily in spray guns, and is suitable for use in low-temperature soldering of pretinned metal parts.—*Cerro de Pasco Copper Corp., New York, N. Y.*

Carbon-steel Taps

A new line of W-S small taps offers increased tap life and more precise threads. They come in standard or special sizes up to No. 2, have up to 260 threads per inch, and permit between 2500 to 4000 threading operations per tap. The cut thread and flutes of the taps are highly polished to reduce drag and fatigue. Cutting edges have great strength due to the radial chamfer; extra chip clearance is provided by the radial flute. Special heat-treating methods applied to the carbon steel produce a hard cutting edge and increased toughness throughout the length of the tap.—*Woodruff & Stokes, Quincy 69, Mass.*

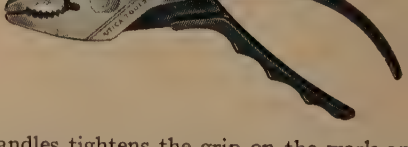


Diffusion Pump

A new fractionating oil diffusion pump, MCF-300, provides a speed of approximately 300 liters per second in the range 10^{-5} to 10^{-3} mm Hg, and with a 4-in. I.D. pump casing. The pump embodies a 3-stage concentric-cylinder type of fractionating jet assembly fitted into an enlarged boiler which permits the use of external electrical heating units without danger of burn-out. The vapor jets are capable of pumping hydrogen 1½ times faster than air, and will operate against a forepressure of 0.150 mm Hg or more, depending on the heater input. Other features are: compact size of water-cooled casing; improved method of centering jet assembly and ease of removal for cleaning; and because of streamlined double-wall jet design, backstreaming is low and thermal efficiency is high.—*Distillation Products, Inc., 755 Ridge Road West, Rochester 13, New York.*

Pliers

A new slip-joint pliers No. 550-8 with offset pistol-grip handle fits the natural hand grip and enables the user to reach hard-to-get-at jobs. Normal pull on the handles tightens the grip on the work and gives more holding power for wire twisting or pulling. The pistol-grip handle provides for efficiency with less effort, reduces wrist fatigue, and prevents slipping and skinned knuckles. The pliers is drop forged of alloy steel.—*Utica Drop Forge & Tool Corp., Utica 4, New York.*



TRADE LITERATURE

Capacitor—"How to Improve Your Load Voltage without Breaking the Camel's Back" titles a booklet describing an improved 3-kvar capacitor. A vector chart assists in determining capacitor kilovar required to increase the power factor to any desired value. Six pages. Bulletin No. 147.—*Cornell-Dubilier Electric Corp., South Plainfield, New Jersey.*

Clamps—Designed for industrial personnel, a new clamp called Neg'ator is described from three aspects: principles, characteristics, and applications. Photographs show typical uses. Four pages. Bulletin 310.—*Hunter Spring Co., Neg'ator Div., Lansdale, Pa.*

Connectors—A manual on electrical lugs, connectors, and accessories, containing color photographs and a thorough compilation of the countless dimensions, ampere ratings, wire sizes, weights, descriptions, etc. so useful to engineers, designers, and others in the industrial field. Seventy pages. Catalog No. 50.—*Ilsco Copper Tube & Products, Inc. Mariemont, Cincinnati 27, Ohio.*

Contact Silver-plating—Instructions for on-the-job silver-plating with Cool-Amp powder are included in a booklet describing its use on all high-amperage current-carrying connections. Six pages 3½ in. by 8 in.—*Cool-Amp Co., 8603 S. W. 17th Ave., Portland 19, Oregon.*

Farm Lighting—Presenting a line of lampholders attached and completely wired to a G-E remote-control unit for operation of Par-38 Floodlamps from many switch locations. Yardlights, Haymowlites, and Coverlites are included. Eight pages. Bulletin No. 122-50.—*Steber Manufacturing Co., Broadview, Illinois.*

Fluorescent Lighting—Titled "Why Quality Costs Less in Fluorescent Lighting," this booklet answers these questions: What are the elements of good fluorescent lighting? Why is the ballast so important? What is the difference in ballast performance? Eight pages. GEA-5317A.—*General Electric Co., Apparatus Dept., Schenectady 5, New York.*

Hermetic Seals—Both standard and custom-designed hermetic seals are covered. Multipoint plugs and multiheads; high-voltage terminals; and solutions of miniaturization, high-altitude, and high-ambient-temperature problems have been given consideration. Photographs introduce different kinds of seals, and engineering drawings provide details of specific alternative designs. Sixteen pages.—*Hermetic Seal Products Co., 37 South 6th St., Newark 7, New Jersey.*

Machining—A pictorial presentation of the machine facilities offered—screw machines, drill presses, punch presses, welding machines, plating tanks, etc.—showing typical parts or items produced by the machines or processes illustrated. Twenty pages. *South Wind Div., Stewart-Warner Corp., 1514 Drover St., Indianapolis 7, Indiana.*

Material Handling—A booklet showing how proper positioning of materials saves unnecessary handlings during production operations. It illustrates and describes 12 different types of equipment of various manufacturers for positioning, and contains two process charts. Titled "Material Handling—At the Machine." Fourteen pages.—*Lyon-Raymond Corp., 15162 Madison St., Greene, New York.*

Plastics—A set of literature consisting of three booklets containing practical information on the properties of molded Plaskon, the technique of molding, applications, characteristics, etc. "Plaskon Hand Book," fifty-eight pages; "Plaskon Molded Color," twelve pages; and "New Concept of Compression Molding," four-pages.—*Plaskon Div., Libbey-Owens-Ford Glass Co., Toledo 6, Ohio.*

Pumps—Cut-away drawings of six types of IMO rotary pumps supplement the brief descriptions of each. Advantages offered by use of these pumps are listed. Four pages. Catalog LG.—*DeLaval Steam Turbine Co., Trenton 2, New Jersey.*

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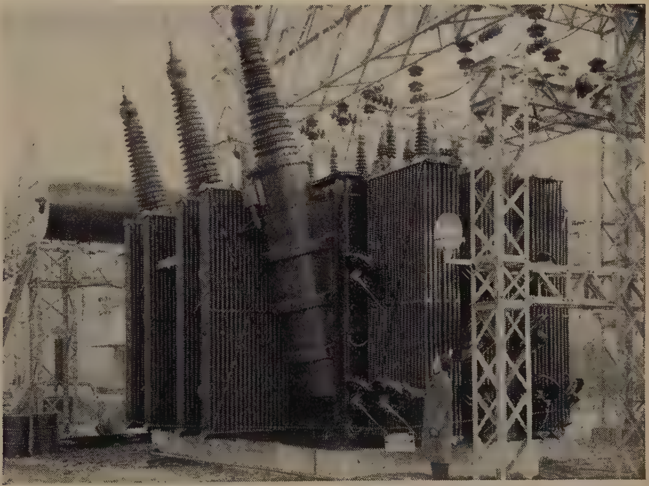

One of two 66,000, 215,000 grd Y—60,000 grd Y—12,000 volt, 60 cycle power transformers built by Canadian General Electric for the Horne Payne substation of B. C. Electric Railway Company.

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ELECTRONICS

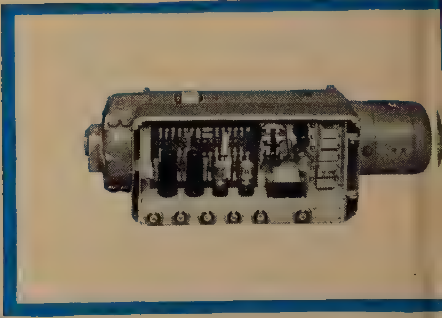
Designers

low-cost welding speeds up production

General Electric engineers have developed a new low-cost method of precision-control resistance welding for use in many expensive assembly operations in the manufacture of electronic equipment.

This new welding method makes it possible for a single operator to weld 15 grounding ribbons and one resistor lead to the chassis of a television set in two minutes.

The control panel shown above provides for welding-current adjustment to control the amount of heat produced in the welds. Once set, this control will keep successive welding currents constant to insure accurate and consistent welding of connections. Write for complete data in Bulletin GEA-4175.

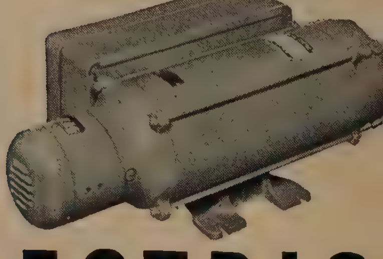


one package— Amplidyne plus Amplifier

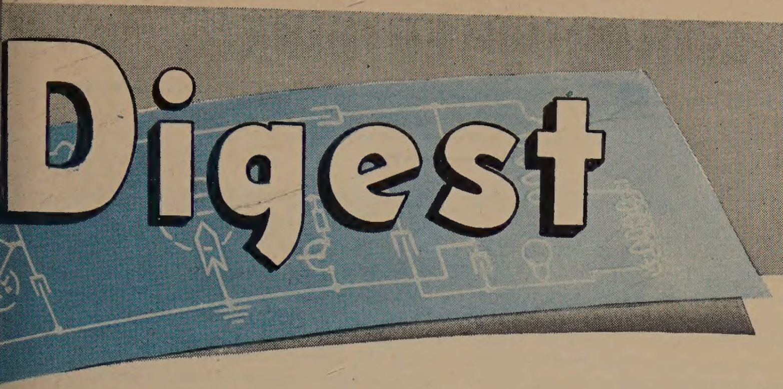
The G-E electronic amplidyne consists of a motor-amplidyne set, a high-gain d-c balanced amplifier, and a reference voltage supply. It is similar to equipments used in drive systems for radar antennas, searchlights, and ship and aircraft gun mounts. Commercially, it can be used in many kinds of motor control systems for close regulation of current, voltage and speed—to limit torque, hold tension, speed up acceleration, and position accurately.

The electronic amplifier makes the amplidyne respond quickly to sudden changes in the control signal, and gives it high sensitivity to small gradual changes. These and other features make it readily adaptable to automatic programming and closed-cycle processing control.

Applications range from power supply for ¼ to 1½ horsepower motors to field excitation for large adjustable voltage drives up to 20 horsepower. For information, see Bulletin GEA-4889.

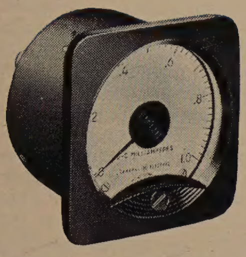


GENERAL ELECTRIC



Digest

TIMELY HIGHLIGHTS ON G-E COMPONENTS

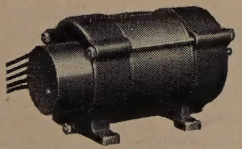


250 degrees of meter scale

General Electric's new long-scale panel instruments are designed for applications where space is limited, but ease and accuracy of reading are required. These 3½-inch instruments have a 4.92-inch scale which covers 250 degrees.

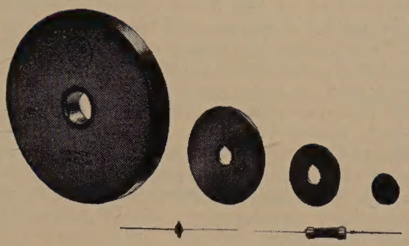
The sturdy, attractive, molded Textolite cases (round or square) harmonize with other G-E panel instruments. The mechanism is the internal-pivot type—a reliable unit construction which permits minimum behind-the-panel depth. Accuracy is within 5% of full scale on the rectifier type, 2% on all others. For full details, write for Bulletin GEA-5425.

If you need it— ± one degree accuracy



Electronic engineers are well aware of the usefulness of selsyns. Whether used for indicating or control, they have proved themselves a reliable, accurate, and rapid means of communication.

G.E. produces a complete line of selsyns—the high-accuracy type with an accuracy of ± one degree, and the general-purpose type with a ± five-degree accuracy. All units have high operating torque and are totally enclosed with no exposed terminals. Indicators and transmitters are also available in several models. See Bulletin GEA-2176.

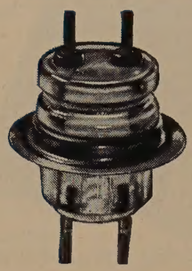


R varies inversely as E^4

Thyrite® resistance material is inorganic and has the unique electrical property of varying inversely in resistance as the fourth power (or even higher) of an applied voltage. It has stable electrical characteristics over a wide range of operating conditions and can be used with a-c, d-c, or short-duration pulses. Because of this, it has solved many problems for the electronic design engineer.

Its most widely known applications are in the limiting of voltage surges, the stabilization of rectifier output voltages, the controlling of voltage-selective circuits, and the potentiometer division of voltages.

It is usually supplied in disk form in diameters from 0.25 to 6.00 inches, with or without mounting holes. Smaller sizes are furnished with wire leads. Complete information is contained in Bulletin GEA-4138.



Cast glass bushings make possible new designs

Originally developed by General Electric for use in vital communication equipment, these unique bushings are now successfully used on such apparatus as power capacitors, transformers (filament, modulator or pulse), and rectifiers. They're made of cast glass with sealed-in nickel-steel hardware and can be readily welded, soldered or brazed directly to the apparatus. This eliminates the need for gaskets and provides a permanent hermetic seal.

Because they are small and compact, as well as vibration and weather resistant, glass bushings make possible new designs, especially where apparatus is to be airborne or where high humidity or fungus growth are special problems. Glass bushings will not puncture or shatter under excess potentials—either 60 cycle or impulse. For more data, including sizes and ratings, see Bulletin GEA-5093.

General Electric Company, Section C667-4
Apparatus Department, Schenectady 5, N. Y.

Please send me the following bulletins:

( ) GEA-2176 Selsyns
( ) GEA-4138 Thyrite Material
( ) GEA-4175 Welding Control
( ) GEA-4889 Electronic Amplidyne
( ) GEA-5093 Glass Bushings
( ) GEA-5425 Panel Instruments

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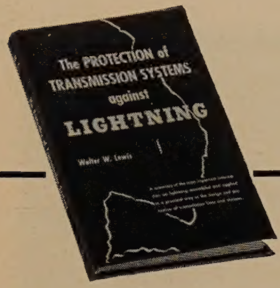
THE PROTECTION OF TRANSMISSION SYSTEMS AGAINST LIGHTNING

By WALTER W. LEWIS



This is the first time all the important information on lightning has been compressed into a single book for the engineer in the power field. The author has applied this information in a practical way to the design and protection of transmission lines. He discusses all significant tests and experiments which have been made since 1924, and describes the instruments which were used in them.

BASIC INFORMATION PLUS PRACTICAL METHODS

The first five chapters give basic information on lightning waves. The rest of the book contains practical rules to guide plant owners, designers, constructors, and operators. Rules are given for the proper co-ordination of line insulation and spacing of conduits for the most effective arrangement of overhead ground wires, and for grounding lines and stations. Thorough coverage is given to alternative methods of protecting transmission lines (both low voltage and high voltage, stations and rotating machines).

January 1950 418 pages $8.00

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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

The A. R. R. L. Antenna Book (5th Edition)

American Radio Relay League, Inc., West Hartford, Conn. 1949. 288 pp. $1.00.

This collection of information on antennas for the amateur radio operator was divided into two general sections. The first treats the operation of antennas and feed systems and their design; the operation is explained in terms of qualitative pictures of fields and standing waves of voltage and current, and the design is presented in the form of simple equations and graphs. The second portion treats the characteristics, construction, and adjustment of the more common antenna systems for receiving and transmitting.

This edition represents a rewriting of the material presented in previous editions of the book and, as such, gives a good coverage of the antenna systems used on the amateur bands below 144 megacycles. It is unfortunate that the new edition does not cover some of the antenna systems for use at the higher frequencies, particularly some of the important developments made during the past nine years.

The radio amateur will find this a very useful book, as it is written with his requirements and background in mind. The engineer will find it to be a handy source of information on the practical aspects of shortwave antenna-system selection and construction.

K. O. Straney

A Textbook of Colloid Chemistry (2nd Edition)

Harry Boyer Weiser—John Wiley & Sons, Inc., New York. 1949. x+444 pp. $5.50.

This book made its initial appearance ten years ago and has now undergone its first revision. The author very carefully states, in the preface, the purposes for which the book has been written, and then accomplishes his goal in masterful fashion.

The systematic order and arrangement of the first edition have been retained; the number of chapters has been reduced by one (chapter 27) but some of the subject matter of the eliminated chapter has been transferred to an earlier one (chapter 16). Although the other principal changes are in chapters 4 and 5, which have been rewritten and expanded, the book in general has been brought up to date. The text has been increased from 404 to 422 pages, but the actual expansion in subject matter is made relatively larger by the space gained with several changes in printing.

The use of a better grade of paper, the assembly of the numerous references (between five and ten percent of the total number refer to the literature of the ten-year interval between editions) at the ends of the chapters, more extensive use of heavy black type, and scarcity of errors are all commendable features. In the opinion of the reviewer the student might benefit from a collection of problems or exercises at the conclusion of a chapter; and personally he would have liked a more extensive and varied treatment of the applications of colloid chemistry even though he appreciates that the author's view was based upon a need for conciseness.

Dr. Weiser's long and distinguished career in the field of colloid chemistry has qualified him to prepare an excellent textbook on this subject; he has done just this.

W. F. Gilliam

Electric-resistance Strain Gages

W. B. Dobie and Peter C. G. Isaac—Macmillan Co., New York. 1949. xiv + 114 pp. $3.50.

Here, for the first time contained under one cover, is all of the pertinent information that the engineer should have at hand when using the electric-resistance strain gage. Because of the simplicity and ease of attachment, many attempts have been made to "simply glue the gage on and get a reading." This has usually resulted in disappointment because of a lack of appreciation of the characteristics and limitations of these gages.

This book's greatest value lies in pointing out all of the characteristics and limitations necessary for the proper application of the gage. Some of these are not appreciated even though such gages are being used in everyday work.

Also included is a reasonably complete presentation of bridge circuits and bridge theory, as well as a description of other intermediate means necessary to raise the power level of the signal obtained from the gage so that it will be sufficient to operate an indicating or recording device. A brief presentation of the indicators and oscillographs available is enclosed in the interest of showing the complete equipment needed.

The chapter on stress analysis, or the interpretation of the resultant oscillograms, will serve in analyzing simple and moderately complex stress problems.

This book is highly recommended for use in the face of actual stress problems, and particularly where it is planned to use electric-resistance strain gages to obtain quantitative measurements.

K. R. Geiser

Electric and Magnetic Fields (Third Edition)

Stephen S. Attwood—John Wiley & Sons, Inc., New York. 1949. xi+475 pp. $5.50.

This third edition of an already well-organized book on electric and magnetic fields provides a smooth transition from the study of mathematics and physics into advanced, professional-level electrical engineering. This transition is brought about by the expression of fundamental field theory in mathematical form, expressing physical ideas in mathematical form, then proceeding to obtain desired solutions in logical, easily understood procedures.

The book is divided into four parts: the electric field, the magnetic field, the ferromagnetic field, and combined electric and magnetic fields. Each part is amply illustrated with drawings and figures; by use of these sketches, and particularly the field plots, a clear physical picture of the problem is obtained.

Though circuits have not been neglected the book places emphasis on the field point of view, in line with the recent trend of attacking more problems from the field mapping viewpoint. Another worthy change that has been made in this edition to bring it up to date is that of using the rationalized mks system of units.

Although written as a text on electric and magnetic fields, the book is recommended as an excellent reference for the analytical engineer who needs a thorough yet easily understandable, reference on the subject.

T. D. Gord

LIBRARY NOTES

ON ARTICLES IN OTHER TECHNICAL JOURNALS

ALLOYS

CRYSTAL ORIENTATION IN MAGNETIC ALLOYS, by Martin Littmann. *Elec. Engng.*, Nov. 1949; v. 68, pp. 977-979.

Three percent silicon-iron and 48 percent nickel-iron alloys are described, wherein the cube edge of the crystals are aligned with the rolling direction of the sheet.

HIGH STRENGTH NICKEL ALLOY RETAINS PERFORMANCE PROPERTIES AT HIGH TEMPERATURES, by C. A. Crawford. *Mat. & Methods*, Oct. 1949; v. 30, pp. 57-61.

How unusually high strength at ordinary temperatures and at red heat is obtained by suitable heat treatment of Inconel X, a recently developed high-temperature alloy.

COLOR MATCHING

VISUAL SENSITIVITIES TO COMBINED CHROMATICITY AND LUMINANCE DIFFERENCES, by W. R. J. Brown and D. L. MacAdam. *Optical Soc. of Am. Jour.*, Oct. 1949; v. 39, pp. 808-834.

Describes an investigation to determine standard deviations of color matchings for representative colors scattered throughout the color domain.

FOUNDRY PRACTICE

ADVANCED CASTING METHODS. *Steel*, Oct. , 1949; v. 125, pp. 68-71, 97-98, etc.

A Navy research program aimed at developing satisfactory methods for producing shrouded steam-turbine wheels cast integrally and jet-engine rotors cast with and without inserted blades.

AND IN THE MILL VS SAND IN THE MOLD, y J. B. Caine. *Foundry*, Oct. 1949; v. 77, p. 68-70, 232-240.

Effective control of certain variables in the use of molding sand is the most important problem facing the foundry industry today, according to the author.

GEAR MANUFACTURE

DEVELOPMENTS IN GEAR PRODUCTION, by I. Pearson. *Engng.*, Nov. 4, 1949; v. 168, p. 487-490.

Describes English methods of gear manufacture.

MODERN GEAR-CUTTING EQUIPMENT, by harles G. Pfeffer. *Am. Mach.*, Oct. 20, 949; v. 93, pp. 87-98.

Summary of principles, types, capacities.

MACHINE DESIGN

XPERIMENTAL AIDS IN ENGINEERING DEGN ANALYSIS, by Walter W. Soroka. *Mech. Engng.*, Oct. 1949; v. 71, pp. 831-837.

A theoretical article on the use of calculating instruments and analogue methods for the solution of difficult problems in mechanical design.

MPACT OF MILITARY REQUIREMENTS ON RODUCT DESIGN, by Alex E. Javitz. *Elec. Mfg.*, Oct. 1949; v. 44, pp. 142-147, 218, c.

Touches on not only their immediate importance in terms of defense contracts but also their incisive, longer-range influence by introducing new concepts of design plus new materials and components.

ACHINE-SHOP PRACTICE

ACK-SLIDING CUTTER MILLS TIGHT CORNERS, by Joseph K. Row. *Am. Mach.*, Oct. 20, 1949; v. 93, pp. 78-79.

Special attachments that make possible radical departures from standard milling practice in close quarters.

HOBBING MOLD CAVITIES IN ALLOY STEELS, by John Sekowski. *Mach.*, Oct. 1949; v. 56 pp. 150-151.

Pertains to the hobbing of molds for plastics.

MEASURING INSTRUMENTS

LIGHT RAYS CAN BE TOOLS, by Allen R. Fultz. *Instruments*, Nov. 1949; v. 22, pp. 1050-1054.

Shows how it is possible to construct various kinds of measuring devices which employ light rays as a component. Special attention to instruments of the contour-projection type.

NEW METHOD MEASURES THE SOLID:GAS RATIO IN HIGH-SOLID FLOW, by J. M. Dotson and others. *Chem. Engng.*, Oct. 1949; v. 56, pp. 128-130.

An electronic method developed for measuring the instantaneous solid:gas flow through a tube when the solid is about 20 percent by volume.

SENSITIVE INDICATOR OF A-C VOLTAGE FLUCTUATIONS, by G. M. Petropoulos. *Jour. Sci. Instr.*, Nov. 1949; v. 26, pp. 372-374.

A dynamometer-type instrument and a nonlinear bridge circuit, for following very small voltage fluctuations in a low-voltage supply.

PLASTICS

SUCCESS IS IN SIGHT FOR THE REINFORCED POLYESTERS. *Modern Plastics*, Oct. 1949; v. 27, pp. 69-76, 158, 160.

On the production, properties, and uses of glass-reinforced plastics.

RADIO ENGINEERING

ACCURATE FREQUENCY MEASUREMENTS, by W. F. Brown. *Wireless Engr.*, July 1949; v. 26, pp. 218-229.

Proposed method for use at frequencies up to 12,000 mc. Measures the frequency difference between the unknown source and a known crystal-checked harmonic of a relatively low-frequency stable reference oscillator.

NEW PORTABLE AUDIO AMPLIFIER FOR AM-FM-TV, by W. W. Dean. *Audio Engng.*, July 1949; v. 33, pp. 11-14, 39.

An amplifier for remote broadcast use to deliver a level suitable for transmission to the broadcast studio.

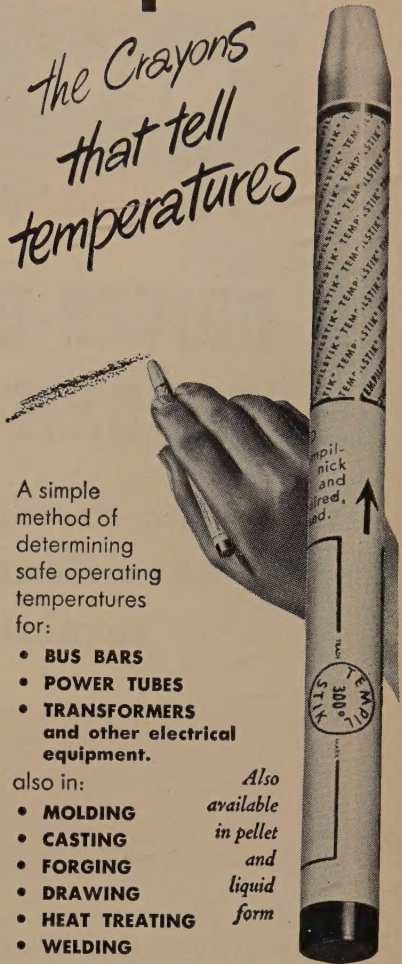
SHOCK WAVES

DISTRIBUTION OF SINGULAR SHOCK DIRECTIONS, by T. Y. Thomas. *Jour. Math. & Physics*, Oct. 1949; v. 28, pp. 153-172.

An extension of the results of several articles, recently written, which deal with shock waves attached to the vertex of a pointed obstacle in a uniform field of flow.

SHOCK WAVES IN ARBITRARY FLUIDS, by Hermann Weyl. *Commun. on Pure & App. Math.*, June/Sept. 1949; v. 2, pp. 103-122.

An investigation which tries to clear up the general hydrodynamical and thermodynamical foundations of the shock phenomenon.



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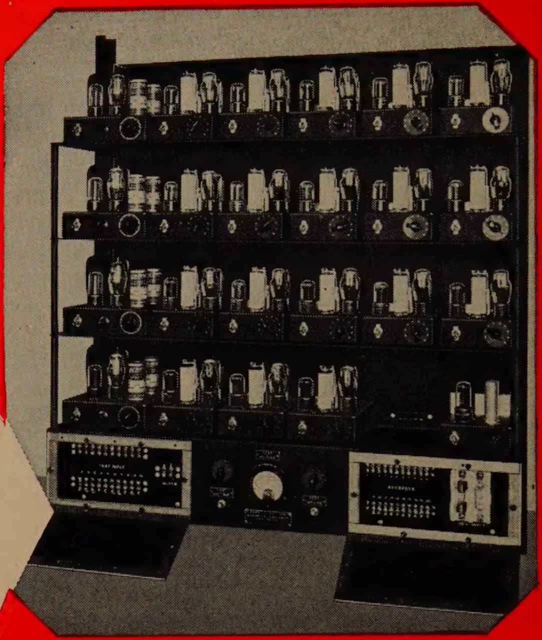

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